

SUPPLEMENTAL REPORT ON HURRICANE OF SEPTEMBER 21, 1938,
AND ITS EFFECTS ON THE COASTAL REGION.

TABLE OF CONTENTS

<u>Paragraph No.</u>	<u>Paragraph Subject</u>	<u>Page No.</u>
<u>SCOPE AND PURPOSE</u>		
1.	Scope	1
2.	Purpose	1
<u>ORIGIN AND HISTORY</u>		
3.	Origin	3
4.	Hurricane Tides	4
5.	Previous Hurricanes	6
6.	Frequency of Hurricanes.	13
<u>1938 HURRICANE</u>		
7.	Path of Storm	15
8.	Barometric Records	16
9.	Winds.	17
10.	Temperature Records	19
11.	Precipitation.	20
<u>1938 HURRICANE TIDE</u>		
12.	Division of Coastal Waters	22
13.	Early Manifestations	22
14.	High Water Times	23
15.	High Water Elevations	29
16.	Wave Action	38
<u>1938 HURRICANE - EFFECTS AND LOSSES</u>		
17.	Loss of Life	46
18.	Effect on Shore Line and Beaches	46
19.	Maddaket, Nantucket, Massachusetts	48
20.	Chatham, Massachusetts	49
21.	Harwich, Massachusetts	49
22.	Yarmouth, Massachusetts.	49
23.	Point Gammon to Nobska Point, Massachusetts	49
24.	Marthas Vineyard, Massachusetts.	50
25.	Cuttyhunk Island, Massachusetts.	50
26.	Woods Hole, Massachusetts	50
27.	East Shore of Buzzards Bay	50
28.	North Shore of Buzzards Bay	51
29.	Horse Neck Beach, Westport, Massachusetts	51
30.	Acoaxet, Westport, Massachusetts	52

1938 HURRICANE - EFFECTS AND LOSSES

31.	Little Compton, Rhode Island	52
32.	Tiverton, Rhode Island	53
33.	Fall River, Massachusetts	53
34.	Somerset, Massachusetts	53
35.	Swansea, Massachusetts	53
36.	Warren, Rhode Island	54
37.	Bristol, Rhode Island	54
38.	Portsmouth, Rhode Island	54
39.	Middletown, Rhode Island	55
40.	Newport, Rhode Island	55
41.	Barrington, Rhode Island	56
42.	East Providence, Rhode Island	56
43.	Cranston, Rhode Island	56
44.	Warwick, Rhode Island	56
45.	North Kingstown, Rhode Island	56
46.	Narragansett, Rhode Island	56
47.	South Kingstown, Rhode Island	58
48.	Charlestown, Rhode Island	58
49.	Westerly, Rhode Island	58
50.	North Shore Fishers Island Sound	59
51.	Fishers Island, etc., New York	59
52.	New London, Connecticut	59
53.	East Lyme, Connecticut	59
54.	Old Lyme, Connecticut	60
55.	Milford, Connecticut	60
56.	Stratford, Connecticut	61
57.	Westport, Connecticut	61
58.	Summary	62
59.	Effect on Inlets and Channels	63
60.	Obstructions and Wreck Removal	64
61.	Damage to Shipping and Pleasure Craft	65
62.	Damage to Bridges and Highways	71
63.	Summary	74
64.	Damage to Railroads	74
65.	Summary	78
66.	Damage to Harbor Structures	79
67.	Summary	85
68.	Damage to Army and Navy Posts	87
69.	Damage to Commercial Property	90
70.	Damage to Private Residential Property	95
71.	Estimated Direct Property Damages By Hurricane Wave.	97
72.	Recapitulation of Damages.	100

CONCLUSIONS

73.	Economic Feasibility of Protection	102
74.	Recapitulation	103
	Figures 1 to 29, inclusive.	
	Plates 1 to 26, inclusive.	

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WAR DEPARTMENT
UNITED STATES ENGINEER OFFICE
PROVIDENCE, RHODE ISLAND

June 17, 1939.

Subject: Supplemental Report on Hurricane of September 21, 1938, and
Its Effects on the Coastal Region.

To: The Division Engineer, North Atlantic Division, New York,
New York.

SCOPE AND PURPOSE

1. Scope. - This report covers only the coastal region within the limits of the Providence U. S. Engineer District. Data on the damages and effects of the hurricane in the interior are not within the functions of this office to assemble. It is understood that some of the States concerned have or are making studies on various aspects of the hurricane.

2. Purpose. - This report supplements a preliminary report submitted on November 12, 1938, in compliance with Division Circular Letter, dated September 23, 1938, File N.A.D. 32/308.1. Additional wind, barometric, tidal, and wave data, for the coastal region of this District, from Chatham, Massachusetts, to Greenwich, Connecticut, have been assembled. The correlation of the various phases of the storm and its effects has been studied. The purpose of this report is to present a more complete discussion of the relation of causes and effects of the hurricane upon the coastal region. The effects upon structures and the nature of failures have been briefly considered

with a view to profiting by the experience when future structures are designed. More complete statistical data on hurricane flood damages have also been compiled. The locations of the various areas considered are shown on the accompanying maps, File No. R. & H. M. 283, included as Figures 1, 2, and 3. Some additional locations outside the coastal region are shown on Figure 4.

This report is not an exhaustive one, but merely supplements an earlier immediate report. This office has not the funds to devote to investigation of a research nature. Such studies would, however, be valuable. They could profitably pursue such individual subjects as the effects of the hurricane on engineering structures, why some stood up and others failed, with a resultant ideal design for the condition to be met; and examinations of hurricane effects on beach and beach structures with a view to determining best measures of beach protection.

ORIGIN AND HISTORY

3. Origin. - The term hurricane generally denotes a cyclonic storm of extreme intensity. Low barometric pressures, high winds, heavy clouds and rain are characteristic of the hurricane. It represents an abrupt large scale conversion of the potential energy latent in atmospheric heat and moisture into kinetic energy. This energy is accumulated in the atmosphere in the region of sultry calms near the equator. This region is called the doldrums. In the North Atlantic Ocean it extends from the vicinity of Cape Verde on the western coast of Africa, westward to the northern coast of South America. This belt lies north of the equator between about 5° and 20° north latitude. The deflective effect of the earth's rotation causes a counterclockwise rotation of the disturbance in the northern hemisphere. Wind movement is not directly toward the low pressure cyclone center, but approaches the center in a counterclockwise spiral. Therefore, the highest wind velocities occur at points to the right of the center of the hurricane path where the spiral wind movement and that due to forward motion of the center are in the same direction. Destruction due to wind is greatest on this side to the right of the center, and it is therefore known as the "dangerous semi-circle."

The beginning of most hurricanes, affecting the eastern coast of North America, has been traced to two locations, the vicinity of the Cape Verde Islands, and the western portion of the Caribbean Sea. From the former location, hurricanes move westward, then turn to the north, frequently crossing the West Indies and sometimes striking the eastern coast of the United States. Hurricanes originating in the Caribbean

generally move northward striking Cuba, the Gulf coast or the eastern coast of the United States. Their energy is generally dissipated before they reach about 30° north latitude. The tracks of these cyclonic storms are determined by the location of adjacent areas of higher pressure.

4. Hurricane Tides. - Hurricanes passing over open water generate a storm wave or tide. This wave is generally the most destructive factor of hurricanes. It accounts for a large proportion of the loss of life and property, when a hurricane crosses the coast line. It is caused by the tractive force of the strong winds and the low barometric pressure of the hurricane center. It appears likely that the wave takes the form of a conical hump of water on the surface of the ocean. Each inch of drop in barometric pressure can account for about one foot rise in the water surface. Probably the vertex of the rise due to drop in pressure lies directly under the low pressure center and advances with it until the coast line is reached. The tractive force of the wind in the dangerous semi-circle apparently affects the ocean to considerable depth, and causes an enormous volume of water to advance in the form of a wave of translation. The elevation of the ocean surface is probably not raised to a great height by this process, until this wave of translation reaches the shore line, when the kinetic energy of the moving water is transformed into potential energy and the water is piled up to abnormal heights. In the northern hemisphere the vortex of this rise would lie to the right of the path of the storm center. The effect of the oncoming hurricane on the tide has been noted considerably in advance of the time when its center reached the coast line.

Both of the foregoing phenomena probably partake of the nature of a

wave of translation similar to that of the ordinary gravitational tide. As such, the tidal stages caused by them would be governed by the same laws as those of the gravitational tide. Thus gravitational tides which amount to only a few feet in the open ocean are transformed in funnel shaped bays to much greater ranges, in some cases amounting to 25 feet or more. The range of the hurricane tide is likewise increased under such conditions. Much of the loss of life caused by hurricanes has been caused by the rapid inundation of the land when these waves of translation reach inhabited low coastal land and byshores.

The hurricane tide is, in point of time, independent of the gravitational tide. If its time coincides with time of gravitational high water, the two effects will be added; if with time of low water, the resulting heights may not be extreme. Extreme heights naturally occur when the time of the hurricane tide coincides with that of high water of a spring tide.

The oncoming hurricane tidal wave is frequently evidenced by exceptional heights of precoding high and low waters, even when local winds are blowing offshore. The effect of the local offshore winds is more than offset by the winds on the opposite side of the hurricane center which cause an accumulation of water along the coast.

In addition to the rise of solid water considered in the foregoing paragraphs, great oscillatory waves are produced by the wind. These waves do not break offshore and roll harmlessly up the beach, but due to the abnormal hurricane tidal stages they break against banks, dunes or structures located above the elevation of mean high water. Breaching of dunes and destruction of practically all structures in their

path can be attributed to this wave attack. The almost continuous wind pressure forces these waves to roll high up sloping beaches and headlands, and holds the water surface higher than in adjacent areas, especially in confined bodies where the water is not free to advance. Excessive high water stages, that cannot be accounted for by the hurricane tidal wave alone, are believed to be caused in this manner.

Oscillatory waves caused by the strong winds in the rear quadrant of the dangerous semi-circle advance in the same direction as the storm center. In this quadrant the winds blow in the same direction for a longer time and waves are built up to greater size. These waves are propagated in advance of the storm itself. A heavy ground swell is observed on the coast to the right of the point where the storm center will strike. Heavy surf where local winds are of insufficient force to produce any material local agitation of the sea is significant of an approaching storm.

5. Previous Hurricanes. - During the period of May to November many tropical cyclonic storms, which affect the eastern coast of North America, occur almost every year. These storms are frequently of hurricane intensity. However, it is a comparatively rare occurrence that one reaches the New England coast before its energy has been almost entirely dissipated. Records have been found of 14 hurricanes that reached the New England States with considerable intensity. The earliest one occurred in August, 1635, and is described by Governor Bradford of Plymouth Colony in his Journal, as follows:

"This year, ye 14 or 15 of August (being Saturday) was such a mighty storme of wind and raine as none living in these parts, either English or Indians, ever saw, Being like (for ye time it con-

tinued) to those Haurricanes and Tuffons that writers make mention of in ye Indcas. It began in ye morning, a little before day, and grue not by degrees, but came with violence in ye begining, to ye great amasmente of many. It blew downe Sundry (211) houses & uncovered others; diuerce vessells were lost at sea, and many more in extreme danger. It caused ye sea to swell (to ye southward of this place) above 20 foote, right up & downe, and make many Indeans to clime into trees for their saftie; it tooke of ye barded rooffe of a house which belonged to the plantation at Manamet, and floted it to another place, the posts still standing in ye ground; and if it had continued long without ye shifting of ye wind, it is like it would have drowned some parte of ye cuntrie. It blew downe many hundred thousand of trees, turning up the stronger by the roots, and breaking the hiegher pine trees of in the midle, and ye tall yonge oaks & walnut trees of good biggnes were wound like a withe, very strang & fearfull to behould. It began in ye south east, and parted toward ye south & east, and vered sundry ways; but ye greatest force of it here was from ye former quarters. It continued not (in ye extremitie) above 5 or 6 houers, but ye violence bogane to abate. The signs and marks of it will remaine this 100 years in these parts where it was sorest. The moone suffered a great eclips the 2 night after it."

The following quotation from the "Documentary History of R. I." describes a disturbance in 1638:

"On June 1, 1638, Winthrop wrote about an earthquake which took place, and again on August 3, 1638, as follows:

"That in the night with a very great tempest or hiracono at S.W. which drave a ship on ground at Charlestown and breaks down the windmill there, and does much other harm. It flowed twice in six hours and about Narragansett it raised a tide 14 or 15 foot above the ordinary spring tides upright."

Tropical storms in 1757, August 1773, September 1804 and October 1804, are reported to have reached Boston, but no further information on them has been found, except that the latter caused considerable damage to shipping and buildings. A tropical storm reached New England on August 19,

1788. The accompanying high water caused damage at New Haven, Connecticut, and the wind damaged buildings and timber inland. On September 23, 1815, a very destructive hurricane with accompanying wave reached the coast of Rhode Island. Its track across New England is shown on Figure 4. Extreme tidal stages in Narragansett Bay flooded the City of Providence. The elevation of the 1815 flood mark as recorded on two tablets located near the head of navigation is 16.2 feet above mean low water. The following quotation is from "Historic Storms of New England" by Sidney Perley:

THE GALE OF SEPTEMBER 23, 1815

The force of the gale was principally and most severely felt in Narragansett bay in Rhode Island. The wind swept the bay, and Providence suffered from its effects more than any other place. From ten to half-past eleven o'clock it blew a hurricane. About the wharves and lower part of the town generally confusion reigned. High water was about half-past eleven o'clock in the forenoon, and the wind brought in the tide ten or twelve feet above the height of the usual spring tides, and seven and a half feet higher than ever known before, overflowing and inundating streets and wharves. The vessels there were driven from their moorings in the stream and fastenings at the wharves with terrible impetuosity, toward the great bridge that connected the two parts of the town. The gigantic structure was swept away without giving a moment's check to the vessels' progress, and they passed on to the head of the basin, not halting until they were high up on the bank. All the vessels were driven ashore, or totally destroyed. There were wrecked in the cove four ships, nine brigs, seven schooners and fifteen sloops. After the storm they lay high and dry, five or six feet above high-water mark, in the streets and gardens of the town.

***On the west side (of the river) the water rushed impetuously through Weybosset street, which was the principal thoroughfare, nearly a yard in depth, turbently carrying along with it boats, masts, bales of cotton, etc., with almost resistless force. It seemed as if that portion of the town was doomed. The store on Bowen's wharf just below where the bridge had

stood still maintained its place, though much injured, but all the stores below, on the east side, were either carried away or so much damaged that they were in a great measure useless. Several dwelling-houses on Eddy's point were carried off, leaving not a vestige behind. In Westminster street, the water was from six to eight feet above the pavements. The Second Baptist church, which was located near the water, was entirely demolished and that of Rev. Mr. Williams, which also stood in a very exposed place, was considerably injured, and if the tide had continued to rise but a few moments longer that, too, must have been destroyed. All the space which but an hour or two before had been occupied by valuable wharves and stores filled with goods, and the river that had been crowded with vessels, were now one wide waste of water raging and furious. Along the higher portion of land were heaped together lumber, wrecks of buildings and vessels of every description, carriages, and bales of cotton, mingled with household furniture, coffee, soap, candles, grain, flour and other kinds of merchandise. Those who witnessed it said that it was a prospect of such widespread desolation and havoc as was beyond description.***

"***Five hundred buildings in all, large and small, were destroyed in this gale and flood, which, with other property that was lost, were valued at fifteen hundred thousand dollars.

"Beside those persons who were wounded and maimed, many valuable citizens were carried with their houses into the water, and others were crushed to death between the planks and the vessels as the latter dashed through the great bridge. No one knows how many human lives were lost in Providence, nor how many cattle were drowned. After the inundation had subsided, a military force of about three hundred was stationed there for several days to prevent pillage of the remaining property that was exposed. No business but that in connection with the storm could be done for some time, the streets having first to be cleared, and then buildings, bridges and wharves rebuilt.

"Providence profited, however, by the great calamity in the general improvement of the town. In the place of dilapidated warehouses, spacious brick buildings arose, new bridges far surpassing the old ones in strength and beautiful design were built, and an elegant and much larger church occupied the site of

that which had been destroyed. Four years after the storm the greatly improved appearance of the place indicated an era of prosperity rather than one of loss and disaster, in spite of the general inactivity of business that had then prevailed for a year or two.

"At Bristol, a short distance from Providence down Narragansett bay, all the vessels were driven a great distance in on the land, and considerably injured. There the tide rose seven feet higher than it was ever known to rise before, and the wharves were completely swept away.***At Point Judith the lighthouse was destroyed, the large fishing rocks at the latter place being removed from their beds.***

"***At New Bedford, all the vessels in the port, except two, were driven ashore, and several of them beaten to pieces.***

"***Some slight damage was done at Falmouth, but in Vineyard sound the water was not so much affected by the wind as in Buzzard's bay.***Farther out on Cape Cod the wind blew much more moderately, and at Provincetown nothing suffered from it.

"Hundreds of vessels other than those mentioned were lost, the newspapers of that time saying that they had not space enough to record the marine disasters. At the eastern end of the Connecticut coast the storm was almost as severe as in Narragansett or Buzzard's bays. At Stonington, the tide rose seventeen feet higher than usual, and swept almost entirely across the town, which is built on a tongue of land running into the water. Everything was washed from the wharves, and then the wharves themselves were demolished. General disaster prevailed among the twenty vessels in the harbor, every one of which was either driven ashore or sunk.***

"***At New London, the storm was severe, and the tide rose so high that it carried away outhouses and fences, and filled cellars, it never having been known to rise there so high before.***"

Two hurricanes are reported in September 1821. The first crossed Long Island and reached New England on September 3, along a path shown on Figure 4. At New York the wind came from the northeast and east, became very strong at 5 p.m. and continued with great violence for three hours.

The damage during two hours was reported as greater than ever previously witnessed in the city. It is stated that the tide rose 13 feet in one hour. The second reached New Haven, Connecticut, on September 25th. No further information on this storm has been obtained.

A tropical storm is reported to have reached Boston on July 24, 1829. On October 3, 1841, a severe tropical storm caused great loss of life and damage to shipping in the vicinity of Cape Cod. The storm wave caused tidal stages two to three feet above the wharves in Nantucket Harbor. The high bank at Siasconset, on the eastern side of Nantucket Island, gave way for some considerable distance, causing several buildings to be precipitated down the cliff. Another hurricane reached Boston on September 10 and 11, 1854. At Boston it was probably not of great intensity, but it is said to have been very destructive as far north as Philadelphia.

A storm of great violence, but narrow width, occurred on September 8, 1869. Perloy describes it as follows:

THE GALE OF SEPTEMBER 8, 1869

***It passed over Narragansett and Buzzard bays in a northerly direction, and when it reached the coast, at Boston, its course changed to the north-east, following the shore as far as Cape Ann. It then swept across the ocean to the coast of Maine, and was felt but a short distance below Portland. The city of Fall River, Mass., was in the middle of the storm belt, but the extremity of Cape Cod escaped the raging elements, and it was only an ordinary storm at Lowell, Mass., and at Nashua, N. H.

"Great damage was done on both land and water. Telegraph wires, trees, fences and chimneys were blown down in every direction, and a great amount of fruit was destroyed. Many roads were blocked with fallen trees, and several tall factory chimneys were blown to the ground.***"

A pamphlet issued in 1869 by Tillinghast and Mason describes the

effect of the 1869 hurricane on Providence as follows:

THE GREAT SEPTEMBER GALE OF 1869 IN PROVIDENCE

"Our city has again been visited by flood and gale, outrivalling in fury and destructiveness the terrible storm of 1815.

"On Wednesday morning, September 8th, the sky was overcast and occasional light showers fell over the city. In the forenoon, the clouds were dispelled somewhat and the sun came out for a short time. About noon, the wind sprang up quite fresh from the southeast blowing up large masses of dark clouds. Between two and three o'clock P.M., it commenced to rain quite freely, the wind in the meantime blowing much heavier. At four P.M., the wind was blowing a perfect hurricane and the rain coming down in torrents. The combined power and fury of the elements were beyond all description. The water in the harbor rose to a great height and poured over the wharves and into the streets in the lower portion of the city with appalling swiftness, at one time rising two feet in twenty minutes.

"Mighty trees were bent by the tempest, some of them being torn up by the roots, and others snapped off like twigs. Boards, bricks, shingles, portions of gates and fences, shutters, signs, and fragments of all kinds filled the air. Massive buildings rocked like toys. Roofs of tons of weight were lifted and carried rods away. Heavy strips of tin and metal were torn from places where they had been securely nailed and blown like sheets of paper for long distances. Steeples rocked and fell. Huge buildings were crushed in like eggshells. Vessels were swept like sticks upon the shore. Dwellings were overturned and carriages blown along the street like feathers. For the first time since the advent of telegraphy in this city, we were without a single 'tap' from 'outside barbarians,' not a wire of either the Western Union or the Franklin lines being in working order. The rise of the water in the harbor was at the rate of a foot every ten minutes.

"The hurricane abated its fury about 5:45 P.M. and very soon afterwards the water rapidly receded, leaving South Water and Dyer Streets completely covered with the wreckage of the gale. The water poured into THE PRESS office in great volume, putting out the fires in the engine room and submerging the printing machinery. An editorial in THE PRESS on the next day says, 'The high water mark in the room where

we write is eighteen inches above the floor and all around there are indications of a great flood, beaten in history only by Noah's celebrated deluge and the great gale of 1815.'

"Citizens who experienced the gale of 1815 say that the gale of 1869 was heavier while it lasted than that of its destructive predecessor. It is almost impossible to compute the damage to property on land and sea, but in our own State alone, it must have amounted to hundreds of thousands of dollars."

Records of the City of Providence indicate that the tide on September 8, 1869 reached a height of 6.2 feet above mean high water, or about 10.7 feet above mean low water.

Hurricanes occurring between 1869 and 1938 appear to have diminished in intensity before reaching New England. Those on October 23 - 24, 1878, August 29, 1893, September 1896, September 16, 1903, September 1904, and August 1933 caused damage in the Middle Atlantic States. City of Providence records indicate a tide of 3 feet above mean high water on August 29, 1893. In addition to sources quoted, information on previous hurricanes has been secured from "Hurricanes" by I. R. Tannehill, published in 1938. The progress of the centers of the hurricanes of September 23, 1815, September 3, 1821, and September 21, 1938, through New England is shown on Figure 4.

6. Frequency of Hurricanes. - From the information obtained on previous tropical cyclonic storms affecting New England, it appears that they occur at intervals averaging little more than twenty years. However, records indicate that those of 1635, 1638, 1815, and 1869 were the most violent in this region, with that of 1938 probably exceeding in intensity all others of record. The average interval between these hurricanes of extreme violence and destruction is therefore about seventy-five years. That the earlier storms were not accompanied by great loss of life and property is due to the fact that the affected regions were sparsely settled at the time, dwellings were not built as close to the shore, roads, bridges and other structures were few except in such centers as New

Haven, Providence, and New Bedford. Each succeeding violent hurricane exacts a greater toll as the development and occupancy of the shore area increases. Many other tropical storms have passed northward along the coast with their centers east of New England. In these cases, the winds have been less severe, being of opposite direction to the progress of the center of the hurricane. About half of the hurricanes enumerated occurred during the month of September.

1938 HURRICANE

7. Path of Storm. - The hurricane of September 1938 was first reported on September 13th at a location not far west of the Cape Verde Islands. It followed the normal westward and slightly northward course of similar storms as it crossed the Atlantic through the trade-wind belt, then swung northward along the eastern coast of United States around the western side of a high pressure area in the Atlantic. The center was reported due north of Puerto Rico and east of the Bahama Islands at 7:30 a.m., E.S.T., on September 18th. It advanced in a curved path northwestward and then northward at a uniform velocity of about 10 to 15 M.P.H., reaching a point east of Jacksonville, Florida, on the evening of the 20th. From this point its path of advance was slightly east of north, but its forward speed increased rapidly to about 60 M.P.H. At this unusual rate it passed east of Cape Hatteras on the morning of the 21st, was off Atlantic City at 1:10 p.m., off Sandy Hook at 2:15, and arrived at the southern shore of Long Island, near Fire Island Inlet, at about 2:45 p.m., E.S.T. It entered Connecticut approximately 5 miles west of New Haven at about 3:30 p.m., E.S.T. The center continued its northward progress at an average rate of 50 to 60 M.P.H. It passed west of Middletown, Connecticut, at 4 p.m., west of Holyoke, Massachusetts, at 5 p.m., and turning slightly west of north passed out of the District about 6 to 6:30 p.m., E.S.T. It passed west of Burlington, Vermont, at 8 p.m., E.S.T. The storm's forward advance was then decreasing rapidly, and the center was diminishing in its depth of gradient. During the night it passed into western Quebec with diminished force and movement. Its track across New England and hourly locations of its center from 3 to 8 p.m., E.S.T., are

shown on Figure 4.

Figures 5 to 13, inclusive, showing isobars at 7 and 11 a.m., and hourly from 1 to 7 p.m., E.S.T., clearly indicate the approach and path of the hurricane low pressure center. Isobars on Figure 5 show the location and gradient at 7 a.m. of the low pressure trough which existed as the hurricane approached. The trough occupied the region extending slightly east of north across the Connecticut valley. The areas of higher pressure offshore on the North Atlantic, and inland toward the Great Lakes forced the hurricane center to advance through this low pressure trough. Barometric data used in plotting isobars were furnished by the Weather Bureau, Coast Guard, and other sources. Isobars shown at intervals of 0.05 inch on Figures 5, 6, and 7 at 7, 11 a.m., and 1 p.m., respectively, indicate the gradual increase in the barometric gradient. Figures 8 to 13, inclusive, give isobars at 0.10 inch intervals and show the steep gradient existing near the center of the storm. The wider spacing of the isobars at the later times indicates the diminishing intensity of the hurricane as it reached northern New England.

8. Barometric Records. - A central area about 10 to 15 miles in diameter appears to have had a barometric pressure of 28.0 inches or lower. As the center progressed northward overland, the central pressure rose. The minimum central pressure west of Burlington, Vermont, was probably about 28.6 inches. This center of lowest pressure is frequently called the eye of the storm. The Coast Guard Station at Bellport, Long Island, reported a barometric pressure of 27.94 inches at 3 p.m., E.S.T. This is the lowest pressure that has come to the attention of this office. Minimum barometric pressures, corrected to sea

level, reported by the Weather Bureau, were as follows:

MINIMUM BAROMETRIC PRESSURES - SEPTEMBER 21, 1938

<u>Location</u>	<u>Time</u> <u>p.m.-E.S.T.</u>	<u>Barometer</u> <u>Inches</u>
Sandy Hook, N. J.	2:15	28.71
New York, N. Y.	2:43-3:00	28.72
Babylon, L. I.	3:00	28.0
Bridgeport, Conn.		28.30
New Haven, Conn.	3:50	28.11
Block Island, R. I.	3:05	28.66
Providence, R. I.	3:30	28.90
Nantucket, Mass.	3:30	29.39
Hartford, Conn.	4:17	28.04
Amherst, Mass.		28.41
Worcester, Mass.		28.68
Boston, Mass.	5:30	29.09
Albany, N. Y.	5:00	28.65
Concord, N. H.		28.91
Hanover, N. H.		28.70
Rutland, Vt.		28.74
Northfield, Vt.	7:30	28.77
Burlington, Vt.	8:00	28.68

Barograph records for locations near the center of the disturbance, as New Haven, Middletown and Hartford, show that the atmospheric pressure declined gradually until about noon on September 21st. From noon until about 4 p.m. the drop was very rapid and amounted to about 1-1/4 inches. The subsequent rise was at about the same rate until about 8 p.m. when the noon pressure had been regained. The rise after 8 p.m. was gradual. Barographs for more distant stations were similar except that the pressure drop was smaller.

It is reported that the eye of the storm was clearly observed at New Haven. Winds that had been easterly since about noon died between 3 and 4 p.m., and were followed by increasing southwesterly winds.

9. Winds. - Wind directions and velocities at selected stations are shown by arrows through the locations on Figures 5 to 13, inclusive.

In the absence of direct observations of instantaneous directions and velocities on the hour, the mean of the movements during the preceding and following hours are shown. Length of arrow indicates the wind velocity in miles per hour to the scale shown. The wind movement in a counterclockwise spiral toward the low pressure center is clearly shown, especially on Figures 9 to 13, inclusive, when the center was over New England. The shift in wind direction at New Haven from east to southwest, on passage of the eye between 3 and 4 p.m., is evident. The region of strongest winds lies in the dangerous semi-circle at a distance of about 75 miles to the right of the storm center.

Maximum 5-minute velocities and directions, with their times of occurrence at selected Weather Bureau stations, are given in the following tabulation and shown on Figure 14. The times indicated are at the end of the 5-minute period. Reported gust velocities are also given in the following table:

WIND DATA - SEPTEMBER 21, 1938.

Location	Maximum 5-Minute Data				Maximum Gust Velocity - M.P.H.
	Time	Velocity	Direction		
	: p.m. - E.S.T. : M.P.H. :	: M.P.H. :	: :		
Albany, N. Y.	: ---- :	42	: W	: --	
Block Island, R. I.	: 2:58 and 3:09 :	82	: SE	: 91	
Boston, Mass.	: 5:30 :	73	: S	: 87	
Burlington, Vt.	: 9:41 :	47	: S	: 56	
Concord, N. H.	: 5:47 :	56	: SE	: --	
Eastport, Me.	: 10:24 :	32	: SE	: --	
Hartford, Conn.	: 3:21 :	46	: NE	: 59	
Nantucket, Mass.	: 3:54 :	52	: SE	: 57	
New Haven, Conn.	: 2:23 :	38	: NE	: 46	
New York, N. Y.	: 3:39 :	70	: NW	: 80	
Northfield, Vt.	: 7:49 :	47	: S	: 52	
Portland, Me.	: 8:37 :	43	: S	: --	
Providence, R. I.	: 4:05 :	87	: SW	: 95	
Milton, Mass. (Blue Hill Observatory)	: ---- :	121	: S	: 183	
Mt. Washington, N.H.	: 5 to 6 :	136	: SE	: --	
Sandy Hook, N. J.	: 3 to 4 :	56	: N	: 66	

Higher velocities at Blue Hill Observatory and Mt. Washington are attributed to the altitude of these stations. One minute gust velocity of 109 M.P.H. was recorded by anemometer at 3:20 p.m., at Fishers Island, New York, when the instrument broke. Gust velocity at this location at 3:35 p.m. was estimated at 120 M.P.H. Estimated maximum velocity reported by observer at Watch Hill Coast Guard Station, Westerly, Rhode Island, was 121 M.P.H.

It is evident that the term "dangerous semi-circulo" was well-chosen. An area about 80 miles in width from Saybrook, at the mouth of the Connecticut River, to Martha's Vineyard and extending northward across eastern Connecticut, Rhode Island, Massachusetts, New Hampshire and Vermont had maximum wind velocities over 5 minute periods ranging from 70 to 90 M.P.H. at low elevations and well in excess of 100 M.P.H. at higher altitudes. Gust velocities in this area were probably in excess of 100 M.P.H. near sea level, and greater than 150 M.P.H. at higher altitudes. The destruction of timber in New Hampshire and Vermont illustrated on Plate 1, is evidence of the wind force in exposed locations at the higher elevations. Much timber was also blown down in the coastal states, as is also illustrated by Plate 1. Many well-rooted high pine trees were broken off at their middle indicating that the wind action was similar to that described by Governor Bradford in 1635.

10. Temperature Records. - From temperature records obtained from the Weather Bureau, isotherms have been plotted on Figures 5 to 13, inclusive. They indicate that a large mass of warm air was located to the east of the Connecticut River in the eastern portion of the low pressure trough. Temperatures of 70° to 80° existing in this region

were unusual for this date. The highest temperature recorded in New England in September was 88° F. at Nashua, New Hampshire, on the 21st. The humidity of the air in the low pressure trough was high. In the lower Connecticut Valley several days of rainfall from the ordinary cross-country storm movement preceded the advent of the hurricane. Probably the warmth and humidity occurring in the region prior to the hurricane was of considerable importance in maintaining the storm in almost undiminished intensity as it crossed New England.

11. Precipitation. - Several days of rainfall due to the normal barometric trough over New England preceded the hurricane. The total precipitation in this region is therefore the combined effect of the hurricane and the preceding storm. There is no way of determining the amount due solely to the hurricane, but a Weather Bureau meteorologist states that three inches is probably a fair estimate. At Providence rainfall on September 21st was light (0.17 inch) and at Nantucket only 0.04 inch fell on that day, while locations in the Connecticut Valley had from 2 to 5 inches. The following tabulation gives precipitation records for September 21, 1938, furnished by the U. S. Geological Survey.

(Tabulation given on following page.)

PRECIPITATION - SEPTEMBER 21, 1938.

<u>Location</u>	<u>Precipitation Inches</u>	<u>Location</u>	<u>Precipitation Inches</u>
<u>VERMONT</u>		<u>RHODE ISLAND</u>	
Barre	2.53	Block Island	1.00
Bellows Falls	1.93	Providence	.17
Burlington	2.85		
East Barnet	2.72	<u>CONNECTICUT</u>	
Essex	3.37	Bills Brook	4.64
McIndoes	2.25	Bloomfield	3.00
Middlesex	2.72	Burlington	4.70
Northfield	2.95	Hartford	3.22
Readsboro	4.42	Hartland Hollow	5.46
St. Johnsbury	2.35	New Britain	2.84
Somerset	1.43	New Haven	3.02
Vernon	3.38	Newington	2.43
Waterbury	3.12	South Meadows	2.18
		West Hartford	2.41
		Woodville	4.59
<u>NEW HAMPSHIRE</u>		<u>NEW YORK</u>	
Concord	2.79	Albany	3.91
Hanover	2.37	New York (Battery Place)	3.71
Manchester	1.44	New York (Central Park)	4.05
Mount Washington	4.51		
<u>MASSACHUSETTS</u>		<u>NEW JERSEY</u>	
Amherst	3.88	Sandy Hook	3.85
Blue Hill	.19		
Boston	.10		
Hoosac Tunnel	5.19		
Lowell	.71		
Nantucket	.04		
New Bedford	.04		
Shelburne Falls	3.57		
Springfield	4.28		
Worcester	2.96		

1938 HURRICANE TIDE

12. The coastal waters of the District have been divided into the following five sections to facilitate the study of the hurricane tide of September 21, 1938:

1. Block Island Sound and Atlantic Ocean (Fishers Island to Buzzards Bay entrance)
2. Long Island Sound
3. Narragansett Bay and Sakonnet River
4. Buzzards Bay
5. Atlantic Ocean (vicinity of Marthas Vineyard), Vineyard and Nantucket Sounds

13. Early Manifestations. - The approaching hurricane tidal wave was manifested early on September 21st. An examination of the Sandy Hook, New Jersey, tide curve reveals that the preceding high water at about 5 a.m. was 0.5 foot higher than its predicted height. The excess of actual over predicted height gradually increased. The low water at about 11:22 a.m. was 1.1 foot higher than predicted. The rise to extreme high water was rapid. The peak was reached at 3:45 p.m., E.S.T., or 1 hour 53 minutes earlier than predicted (5:38). Other stations for which heights of the preceding high and low waters are available show similar excess of actual over predicted height. As might be expected, the relative effect was much greater at stations east of the storm center. Thus, as shown in the following tabulation, the excess height of the preceding high water was 28 and 27 per cent of the predicted range at New London, Connecticut, and Woods Hole, Massachusetts, respectively, located east of the storm center, against 9 and 12 per cent for Sandy Hook and The Battery, New York, located west of the center. Similarly, excess heights

of the preceding low water at New London and Woods Hole were 41 and 45 per cent of the predicted range, compared with 20 and 14 per cent at Sandy Hook and The Battery, respectively. The smaller percentage of excess height at the latter locations may be attributed to the larger ranges in that area and the adverse winds on that side of the storm center. Observed and predicted tide curves for New London and Woods Hole for September 21, 1938, based on heights furnished by the U. S. Coast and Geodetic Survey and other sources are included as Figures 15 and 16, respectively. The tide curve from an automatic gage at Harwich, Massachusetts, is shown on Figure 17. Preceding low waters occurring earlier and not falling as low as predicted at New London, Woods Hole, and Harwich, indicate a sudden increase in the volume of water arriving along the coast about an hour before predicted time of low water. Data on preceding tides at four stations are listed in the following table.

TIMES AND HEIGHTS OF PRECEDING TIDES - SEPTEMBER 21, 1938.

Elevations are referred to mean sea level

Location	: Eastern Standard Time :		: Height in Feet :		: Excess Height	
	: Predicted :	: Observed :	: Pre- dicted :	: Ob- served :	: Ft. :	: % of Pre- dicted Range
	: High Water :		:	:	:	:
Sandy Hook, N.J.	: 5:17 a.m. :	: 5:00 a.m. :	2.8 :	3.3 :	0.5 :	9
The Battery, N.Y.C.	: 5:58 a.m. :	: 5:45 a.m. :	2.6 :	3.2 :	0.6 :	12
New London, Conn.	: 6:44 a.m. :	: 6:45 a.m. :	1.5 :	2.3 :	0.8 :	28
Woods Hole, Mass.	: 5:36 a.m. :	: 5:30 a.m. :	1.1 :	1.7 :	0.6 :	27
	: Low Water :		:	:	:	:
Sandy Hook, N.J.	: 11:22 a.m. :	: 11:20 a.m. :	-2.6 :	-1.5 :	1.1 :	20
The Battery, N.Y.C.	: 12:04 p.m. :	: 12:30 p.m. :	-2.5 :	-1.8 :	0.7 :	14
New London, Conn.	: 1:08 p.m. :	: 12:45 p.m. :	-1.4 :	-0.2 :	1.2 :	41
Woods Hole, Mass.	: 1:10 p.m. :	: 11:30 a.m. :	-1.1 :	-0.1 :	1.0 :	45

14. High Water Times. - High water of the hurricane tide is reported to have reached the south shore of Long Island about 3 p.m., E.S.T., about

2 hours earlier than predicted. The normal gravitational high tide along the south shore is earliest in the vicinity of Fire Island Inlet. It reaches Sandy Hook to the west about 35 minutes later, and Montauk Point to the east about 50 minutes later. The high water of hurricane tide propagated in a similar manner. It reached Sandy Hook at 3:45 p.m. and was reported about 3:30 p.m. at Bridgehampton, or about 45 and 30 minutes later, respectively, than at Fire Island Inlet. High water at Montauk Point was probably at about 3:30 p.m., or about 2 hours and 20 minutes earlier than predicted. That it was more advanced relative to the time of the gravitational tide at this location than at Sandy Hook and Fire Island Inlet may be attributed to the greater effect of the wind generated wave of translation in the "dangerous semi-circle."

Approximate locations of half-hourly high water cotidal lines for the predicted gravitational high water, and for the combined hurricane and gravitational high water of September 21, 1938, are shown on a drawing included as Figure 18. Those cotidal lines, which show locations at which high water occurred simultaneously, were plotted using times selected as being most reliable of all times reported for each location. Cotidal lines showing locations having the same predicted time were plotted from predictions in the Coast and Geodetic Survey Tide Tables. The hurricane tidal wave was probably circular in plan. The location of maximum tidal amplitude probably did not coincide with the path of the low pressure center, but was east of it. This might be expected since the winds of the "dangerous semi-circle" were a more potent tide-producing force than the low barometric pressure. The path of the vertex appears to have approached the vicinity of Block Island Sound. To the west, Long Island

being farther south was affected earliest. To the east at Marthas Vineyard and Nantucket, near the rim of the conical hump of water, the peak of the rise occurred later. These times indicate the semi-circular shape of the wave front. High water in this district occurred earliest, about 3:30 p.m., E.S.T., at Block Island, Rhode Island, and reached the western portion of the Rhode Island shore line about one hour later. East of Block Island the peak of the surge reached Point Judith about 4:45 p.m. and Brenton and Sakonnet Points about 5 p.m. The hurricane tidal wave moving into Block Island Sound impressed a wave on the waters at the eastern entrance of Long Island Sound at about 4 p.m., E.S.T., about 2-3/4 hours before the peak of the gravitational tide was predicted. Similarly, the waves in Narragansett Bay and Buzzards Bay were impressed at the entrances to these bays about 5:15 p.m., E.S.T. The shape of the wave front of the gravitational tide is evidently not similar to that of the hurricane wave. Probably the former approaches from the southeast and the latter from a little west of south. The portion of the front of the gravitational wave approaching between Block Island and Marthas Vineyard is farthest advanced, and was predicted at the entrance to Narragansett and Buzzards Bays about 5:30 p.m. Therefore, the hurricane tide was only about 1/4 hour earlier than the gravitational tide at these entrances. This was an important factor in the resulting high waters, as the peaks of the gravitational and hurricane waves nearly coincided in Narragansett and Buzzards Bays.

The propagation of the peak of the combined hurricane and gravitational tidal wave westward through Long Island Sound began at the entrance about 2-3/4 hours before predicted time of high water. At this time the

gravitational tidal stage had reached about two-thirds of its predicted height. The westward propagation of the combined waves was apparently retarded by a total of about one hour. High water reached Bridgeport, Connecticut, about 2 hours earlier than predicted, and Willets Point, New York, at the western end of the Sound about $1\frac{3}{4}$ hours earlier than predicted. This retardation indicates that the wave possessed characteristics of the progressive type of wave. Strong west and southwest winds over the Sound during this period may have contributed to this retardation. As the time difference between actual and predicted high waters decreased toward the western end of the Sound, the gravitational tidal stage reached a greater proportion of its predicted height, and thus contributed more to the peak heights. Observed tidal heights at Bridgeport, Connecticut, as reported by the City of Bridgeport are shown on Figure 19.

Tidal curves for stations in the vicinity of New York City show both the direct effect of the surge which reached the south shore of Long Island about 3 p.m., and the secondary effect of the wave after its westward propagation through Long Island Sound. The direct effect caused the major peak at Sandy Hook at 3:45 p.m., was propagated through New York Harbor and East River causing minor peaks successively at Mill Rock, Hell Gate at 4:15, and at Willets Point at about 4:20 p.m., E.S.T. The secondary effect caused the major peak first at Willets Point at about 7:50 p.m., then at Mill Rock about 7:55, and a minor peak at Sandy Hook about 9:30 p.m., E.S.T. It is noted that at time of predicted high water at Sandy Hook, and shortly before predicted high at Mill Rock, actual stages were lower than predicted stages. This was probably due to the strong offshore winds which would have kept tidal levels considerably lower

than normal if the hurricane tidal wave had not been superimposed upon them.

The propagation of high water of the combined waves into Narragansett Bay began about 5 p.m., E.S.T., or about 1/2 hour earlier than predicted for the gravitational tide. The relatively narrow passages east and west of Conanicut Island at the entrance probably retarded the surge. Time of high water at Newport (about 5:30 p.m., E.S.T.) coincided with predicted time (5:32) as nearly as can be determined. At Providence, at the head of the Bay, the same condition existed. Predicted time of high water for Providence was 5:52 p.m., and no deviation of time of actual tide could be determined. From Newport to Providence the speed of propagation apparently was similar to the normal speed of the gravitational tide. Tidal curves showing the peak of the rise at Newport and Providence were reconstructed from stages and times reported by various sources, and are included as Figures 20 and 21, respectively. The propagation of the surge in Sakonnet River and Mount Hope Bay was similar to that in Narragansett Bay. High water at Fall River occurred about at its predicted time, 5:47 p.m., E.S.T. At Somerset, Massachusetts, on Taunton River, opposite Fall River, the Montaup Electric Company furnished observed heights which are shown on Figure 22. High water was reported at 5:52 p.m. or at about the predicted time.

High water reaching the mouth of Buzzards Bay about 5 p.m., E.S.T., or about 3/4 hour earlier than predicted, was propagated to New Bedford and the head of the bay by about 5:45 p.m. At the latter two locations, the predicted and actual times of high water were almost the same. A tide curve for New Bedford, reconstructed from reported heights, is included as Figure 23.

Along the south side of Cape Cod east of Nobska Point, and along the northeast side of Marthas Vineyard the gravitational tide was about one to four hours later than the hurricane tide. At Nobska Point predicted time of high water was 6:57 p.m., E.S.T., and actual time about 6 p.m. At Edgartown and east of Succunnesset Point on Cape Cod predicted times are from 9:35 to 9:45 p.m. Since the hurricane high water reached this region about 6 p.m., the gravitational stage at that time was probably below half tide level, and the flood stage of the combined waves was much lower in this area.

Table 1 following gives best available data on times of high water on September 21, 1938, at various locations in the district, and also the comparison with predicted times.

Tablo 1

PREDICTED AND REPORTED HIGH WATER TIMES - SEPTEMBER 21, 1938

<u>Location</u>	<u>Times of High Water</u>		<u>Approximate Difference Hours</u>
	<u>P.M.-E.S.T.</u>	<u>Reported P.M.-E.S.T.</u>	
Maddaket, Nantucket, Mass.	6:02	5:30	-1/2
Harwich, Mass.	9:40	6	-3 3/4
Edgartown, Marthas Vineyard, Mass.	9:40	5:30	-4 1/4
Woods Hole, Mass.	6:02	6	---
New Bedford, Mass.	5:42	5:45	---
Acoaxet, Westport, Mass.	5:40	5	-3/4
Fall River (Somerset), Mass.	5:55	5:52	---
Sakonnet, R. I.	5:32	5	-1/2
Tiverton, R. I.	5:52	5:50	---
Portsmouth, R. I.	5:42	5:40	---
Newport, R. I.	5:32	5:30	---
Brenton Pt., Newport, R. I.	5:25	5	-1/2
Bristol, R. I.	5:42	5:40	---
Providence, R. I.	5:52	5:50	---
Pt. Judith, R. I.	5:42	4:45	-1
Block Island, R. I.	5:40	3:30	-2 1/4
Charlostown, R. I.	6:15	4:30	-1 3/4
Fishers Island, N. Y.	7:00	4:20	-2 3/4
New London, Conn.	7:11	4:45	-2 1/2

Location	Times of High Water		Approximate Difference Hours
	Predicted	Reported	
	P.M.-E.S.T.	P.M.-E.S.T.	
Saybrook, Conn.	8:06	5:15	-2 3/4
Now Haven, Conn.	9:21	6:45	-2 1/2
Bridgeport, Conn.	9:26	7:30	-2
Stamford, Conn.	9:26	7:45	-1 3/4
Willetts Point, N. Y.	9:36	7:50	-1 3/4
Hell Gate, N. Y.	8:20	7:55	-1/2
The Battery, N. Y.	6:20	4:30	-1 3/4
Sandy Hook, N. J.	5:38	3:45	-2
Fire Island Inlet, N. Y.	5:03	3	-2
Montauk Point, N. Y.	5:51	3:30	-2 1/4

15. High Water Elevations. - The elevations of more than 100 high water marks were determined by this office. Other high water elevations were secured from various sources. Profiles of high water elevations along the north side of Block Island Sound, the north side of Long Island Sound, the shores of Narragansett Bay and Buzzards Bay, and the shores of Vineyard and Nantucket Sounds are shown on Figures 24, 25, 26, and 27, respectively. Due to differences in exposure of the various locations, considerable variation exists in high water elevations. An average line has been drawn, the purpose of which is to represent the approximate still water height of the combined hurricane and gravitational tides in the open water along the outer shore by eliminating excessive heights due to wave splash and the lesser heights in sheltered locations. Elevations have been referred to mean tide level on these profiles. Profiles of mean high and mean low waters have been included. Heights above either datum plane can be secured from these graphs. High water throughout Long Island Sound occurred about two hours earlier than predicted. The true effect of the hurricane wave on water elevations must therefore be obtained as the difference between total heights and predicted stages

at the time of actual high water. Profiles of these predicted stages are therefore included on the graphs. Actual and predicted times differed little in Narragansett and Buzzards Bays. The hurricane tide was therefore superimposed on practically the peak height of the gravitational spring tide.

Reported high water elevations along the north shore of Block Island Sound from Race Point, Fishers Island to Westport, Massachusetts, are shown on Figure 24. Reported heights for Fishers Island (except Race Rock Light) are for locations on the sheltered north side of the island. Actual heights on the exposed south side would probably be considerably higher. The difference between average high water profile and predicted stage is about ten feet at the western end of Block Island Sound, and increases gradually along the south shore of Rhode Island. A maximum difference of about 17 feet is indicated at Point Judith and Brenton Point, with about 15 feet at Sakonnet Point. At Acoaxet in Westport the difference appears to be about 13 feet. These differences indicate that the vertex of the hurricane wave approached the vicinity of Block Island and Narragansett Bay. The greatest reported still water elevation was in the fog whistle house at Point Judith, where the water mark was 22.1 feet above mean low water. It does not seem likely that still water of the hurricane tide reached this height. This location is very exposed, and it appears more likely that part of the water thrown up by the waves ran into this building. Other excessive heights are 21.6 foot and 19.8 foot above mean low water at Brenton and Sakonnet Points, respectively. These marks were in the open in exposed locations. Probably wave action contributed considerably to these heights.

As shown on Figure 25, the average effect of the hurricane was an addition of 9 to 10 feet to predicted stages in the narrow portion of Long Island Sound from the entrance to Saybrook, Connecticut. The effect decreased to a minimum of about 7 feet in the wide portion near Bridgeport, Connecticut, and increased to about 9 feet in the converging western end of the Sound.

The average increased height of water due to the hurricane, at locations in Narragansett Bay, is shown on Figure 26. The effect gradually increases from about 9 feet in Newport Harbor to about 13 feet in Providence Harbor. The increase in effect with distance from Newport is similar to the increase in the mean range of the gravitational tide. A close similarity of the hurricane wave to the gravitational wave in Narragansett Bay is indicated.

In Buzzards Bay the difference between average actual, and predicted stages, as shown on Figure 26, increases from about 9 to about 12 feet from Cuttyhunk, Massachusetts, to the head of the bay. The increase is similar to that of the mean range between these locations.

On the south side of Marthas Vineyard an observer states that the water rose 13 or 14 feet above the usual level in one of the coves of Edgartown Great Pond, although this pond is separated from the ocean by a low barrier beach. He reports that the rise was exceedingly rapid. On the north side of the island elevations of about 8 feet above mean low water were reported.

The high water profile for Vineyard and Nantucket Sounds is shown on Figure 27. It falls off rapidly to the east. However, it is evident that the comparatively low stages reached east of Succomasset Point

were due to the fact that the peak of the hurricane surge reached this area about four hours in advance of that of the gravitational tide. The hurricane wave was therefore superimposed upon stages of the gravitational tide below half tide level. As may be seen on Figure 27, the increases in height over predicted stages due to the hurricane amounted to about 9 feet at Cuttyhunk, 8 feet at Woods Hole, 7 feet at Succunnesset Point, and 6 feet east of Hyannis. It is interesting to note that the decrease in effect due to distance from the center of the surge is much smaller than that due to the difference in time of the two waves.

Included as Figure 28 is a graph showing the variation of the hurricane wave head above predicted stage at time of peak height along the district outer shore from Greenwich, Connecticut, to Chatham, Massachusetts, and in Narragansett and Buzzards Bays. The effect of the gravitational stage is therefore eliminated, and the comparative effect at various locations, due solely to the hurricane wave, is readily seen. The centering of the surge in the Narragansett Bay area is apparent. The similarity of the hurricane and gravitational waves in Narragansett and Buzzards Bays is indicated. The normal gravitational wave in Long Island Sound is a combination of the stationary and progressive types of tide wave with the former predominating. Corresponding stages of tide occurring almost simultaneously throughout a body of water, and gradual increase in range from one end of the body to the other are typical of the stationary wave, while gradual propagation and little variation in range are characteristic of the progressive type. As may be seen on Figure 18, the normal gravitational wave propagates from a point midway between Saybrook and New Haven, Connecticut, nearly to the western end

of the Sound in about one-half hour. This fact and the increase in mean range, as shown on Figure 28, indicate the predominance of the characteristics of the stationary type of wave. As may be seen on Figure 18, the combined hurricane and gravitational wave took almost two hours to propagate the same distance, and as shown on Figure 28, the hurricane wave did not have the increase in head from Saybrook to Greenwich, Connecticut, corresponding to that of the gravitational mean range. The slower rate of propagation and the smaller variation in height of the combined hurricane and gravitational waves, as compared with the gravitational waves, indicate that the hurricane wave had more of the characteristics of the progressive type of wave in Long Island Sound.

An observer at Westport, Massachusetts, who waded in water waist deep, remarked on the warmth of the water. This fact indicates the possibility that part of the water which piled up along the coast had been driven north from warmer latitudes.

High water elevations determined by this office and those furnished by the Massachusetts Department of Public Works are given in Table 2 following:

(Table given on following page.)

Table 2

HIGH WATER ELEVATIONS - SEPTEMBER 21, 1938

<u>Location</u>	<u>Elev. Still</u> <u>above or</u> <u>M.L.W. Open</u> <u>in ft. Water</u>	<u>Remarks</u>	<u>Bench</u> <u>Mark</u>
<u>MASSACHUSETTS</u>			
Marthas Vineyard:	8.2 : Open :	Entrance to Menemsha Pond	: C.&G.S.
Woods Hole	: 11.4 : Still :	Marine Biological Lab. Supply Bldg.	: C.&G.S.
	: : :	Eel Pond	: :
Woods Hole	: 10.8 : Open :	Marine Biological Lab. Grass Contour	: C.&G.S.
	: : :	Great Harbor	: :
Woods Hole	: 9.7 : Still :	Bureau of Fisheries Bldg., Great Hbr.	: C.&G.S.
Cape Cod Canal	: 16.6 : " :	Wings Neck Light	: U.S.E.
Cape Cod Canal	: 15.7 : " :	Monument Beach	: :
Cape Cod Canal	: 15.7 : " :	State Pier	: :
New Bedford	: 15.9 : Open :	Slocum St. Bridge near Head of Navig.	: City
New Bedford	: 15.3 : " :	Mitchell and Coggeshall Sts. near Head :	: "
	: : :	of Navigation	: :
New Bedford	: 14.7 : " :	City Pier No. 3 near Head of Navigation:	: "
New Bedford	: 13.3 : " :	Rodney Branch Blvd. Clark Cove	: "
New Bedford	: 15.6 : " :	Ft. Rodman Clark Point	: "
Acoaxet	: 17.5 : " :	Debris, Atlantic Ave. outer shore	: C.&G.S.
Fall River	: 15.5 : " :	American Linen Mill, Head Navigation	: City
Fall River	: 15.7 : Still :	Shell Oil Depot, East Side Taunton R.	: "

Furnished by Massachusetts Department of Public Works

Chatham	: 7.2 :	: Stage Harbor	
Harwich	: 7.0 :	: Witchmere Harbor	
Yarmouth	: 6.7 :	: Point Garmon	
Hyannisport	: 7.5 :	: Hyannis Harbor, Imp. Assn. Wharf	
Falmouth	: 7.8 :	: Menauhant Road at Bowon Pond	
Falmouth	: 7.4 :	: Davisville Road, Falmouth	
Falmouth	: 9.3 :	: Menauhant Road, East of Great Pond	
Falmouth	: 8.5 :	: Menauhant Road at Great Pond	
Falmouth	: 8.2 :	: Menauhant Road at Little Pond	
Falmouth	: 8.6 :	: Falmouth Heights near Little Pond	
Falmouth	: 10.9 :	: Grand Ave., Falmouth Heights	
Falmouth	: 7.9 :	: Clinton St., Falmouth Harbor	
Falmouth	: 8.5 :	: Beach Road and Surf Drive, Salt Pond	
Falmouth	: 6.5 :	: Nobska Point	
Falmouth	: 9.2 :	: Nobska Pond, Nobska Point	
Falmouth	: 10.2 :	: Woods Hole, Little Harbor	
Falmouth	: 9.7 :	: Woods Hole, Oceanographic Inst.	
Falmouth	: 15.9 :	: Chappaquoit Island, W. Falmouth Harbor	
Falmouth	: 15.6 :	: New Silver Beach, North Falmouth	

<u>Location</u>	Elev. above M.L.W. in ft.	Still or Open Water	<u>Remarks</u>	<u>Bench Mark</u>
Bourne	: 18.7:		:Monument Beach	
Bourne	: 18.1:		:Back River Harbor	
Bourne	: 15.8:		:State Pier	
Wareham	: 16.3:		:Point Independance, Onset	
Wareham	: 15.8:		:Main Street along Wareham River	
Wareham	: 15.9:		:Main Street along Wareham River	
Wareham	: 12.5:		:Weweantic River Bridge	
Marion	: 16.8:		:Sippican Harbor	
Marion	: 18.8:		:Great Hill	
Mattapoisett	: 15.3:		:Mattapoisett Harbor	
Fairhaven	: 13.9:		:Upper End Sconticut Neck Road	
Fairhaven	: 14.1:		:New Bedford - Fairhaven Bridge	
New Bedford	: 14.5:		:Rodney French Blvd., Clark Point	
Dartmouth	: 12.5:		:At Bridge over Apponagansett Bay	
Westport	: 9.9:		:Hix Bridge	
Fall River	: 16.1:		:Lower End City Wharf, Water Street	
Somerset	: 15.3:		:Riverside Avenue at Bridge, Route 6	

RHODE ISLAND

Sakonnet	: 19.8:Open	:On Bluff, Sakonnet Point	:C.&G.S.
Sakonnet	: 15.4: "	:Inland, at Round Pond	: "
Tiverton	: 17.3: "	:On rock outcrop, NW end of	: "
	: :	: Nannaquaket Cove	: "
Tiverton	: 15.5: "	:On slope of road, NW end of	: "
	: :	: Nannaquaket Cove	: "
Tiverton	: 17.5: "	:At railroad bridge, Sakonnet River	: "
Tiverton	: 14.9: "	:On road, Sinclair Oil Depot	: "
Portsmouth	: 16.5: "	:On house opposite Bristol Ferry Depot	: "
Portsmouth	: 16.1: "	:Debris opposite Bristol Ferry Depot	: "
Middletown	: 14.1:Still	:In boiler room, Melville Fuel Depot	:U.S.N.
Newport	: 14.8:Open	:On fence, near Newport Beach	:City
Newport	: 15.1: "	:On stone, near Bailey's Beach	: "
Newport	: 15.3: "	:On tree, near Bailey's Beach	: "
Newport	: 16.8: "	:On tree, Ocean Av., near Price Neck	: "
Newport	: 16.1: "	:On Tol. Polo, " " " " "	: "
Newport	: 21.6: "	:On Tol. Polo, " " Brenton Point	: "
Newport	: 20.7: "	:On tree, Atlantic Ave., " "	: "
Newport	: 20.3: "	:Debris, Country Club " "	: "
Newport	: 18.8: "	:Sand Contour, " " " "	: "
Newport	: 13.0:Still	:Ft. Adams, in bldg. north end of port	:C.&G.S.
Newport	: 11.4: "	:Ft. Adams, in bldg. south end of port	: "
Newport	: 12.1:Open	:On Wall, Wollington Ave., Newport	:City
Newport	: :	: Harbor	: "
Newport	: 11.8: "	:On bldg. Commercial Wharf, Newport	:C.&G.S.
	: :	: Harbor	: "

<u>Location</u>	<u>Elev. Still above or M.L.W. Open in ft. Water</u>	<u>Remarks</u>	<u>Bench Mark</u>
Newport	: 12.2:Open	:On bldg. Harrington St., Newport Harbor	City
Newport	: 11.9: "	:On fence Wellington Av., " "	: "
Newport	: 11.7:Still	:In shed,Newp.Gas & Lt.Co. " "	: "
Newport	: 13.5:Open	:Mean contour on grass,Naval Train.Sta.:	C.&G.S.
Bristol	: 15.2: "	:On shed,Herreshoff Boat Yard, Bristol	: "
	: :	: Harbor -	: "
Bristol	: 16.2: "	:On fence, Lighthouse Service Dock,	: "
	: :	: Bristol Harbor	: "
Bristol	: 15.8: "	:In doorway,Collins & Aikman Plant,	: "
	: :	: Bristol Harbor	: "
Bristol	: 15.2: "	:On wall, Perry's Cafe,Bristol Harbor	: "
Bristol	: 16.0: "	:On fence, near railroad yards" "	: "
Warren	: 17.3: "	:On fence,Burr Hill Park, Warren River	:R.I.
Warren	: 12.8: "	:On pole between Warren & Barrington	: "
	: :	: Bridges	: "
Warren	: 15.2: "	:On shed near Bridge over Kickimuit R.	: "
Barrington	: 16.7: "	:On tree,Adams Pt. Road, Adams Point	: "
Barrington	: 17.2: "	:On tree, Rumstick Rd., Rumstick Neck	: "
Barrington	: 17.6: "	:On tel. pole, Bay Rd., Barrington Beh.:	: "
Barrington	: 18.2: "	:On tel. pole, Watson Av., " "	: "
Barrington	: 18.3: "	:Grass contour on lawn, " "	: "
Barrington	: 17.4: "	:On house, Bay Spring Av., W.Barrington:	: "
East Providence	: 17.7: "	:On lawn near railroad, Bullock Cove	: "
East Providence	: 17.2: "	:Washout on tracks, " "	: "
East Providence	: 17.9: "	:Chafe line on trestle across Bullock	: "
	: :	: Cove	: "
East Providence	: 18.3: "	:On walk near trestle across Bullock	: "
	: :	: Neck	: "
East Providence	: 18.2: "	:Debris line near Crescent Park Ball-	: "
	: :	: room, Bullock Neck	: "
East Providence	: 18.0: "	:On foundation, Crescent Park Ball-	: "
	: :	: room, Bullock Neck	: "
East Providence	: 18.0: "	:In railroad cut, Socony Vacuum Dock	:C.&G.S.
East Providence	: 19.0: "	:On Barrington Pkway, Watchemoket Cove	:U.S.E.
East Providence	: 18.0: "	:In railroad cut 1/2 mile north of Rod	:U.&G.S.
	: :	: Bridge, Seekonk River	: "
East Providence	: 16.1: "	:On tree inside Greenwood Pt., Ten-	:City
	: :	: Mile River	: "
Providence	: 18.0: "	:Debris 1/2 mile north of Rod Bridge,	:C.&G.S.
	: :	: Seekonk River	: "
Providence	: 17.7: "	:On wall 1/4 mile north of Rod Bridge,	: "
	: :	: Seekonk River	: "
Providence	: 17.6:Still	:R.I. Hospital Trust Bldg. inside NW	: "
	: :	: door	: "
Providence	: 17.7: "	:New Federal Bldg. - inside	: "

<u>Location</u>	<u>Elev. Still above or M.L.W. Open in ft. Water</u>	<u>Remarks</u>	<u>Bench Mark</u>
Providence	: 18.5 : Still:	Harbor Masters Office, Point St. Bri.	: City
Providence	: 18.5 : "	: Field Point	: "
Conimicut	: 16.3 : "	: In house, Bay Av., Conimicut Point	: R. I.
Rocky Point	: 17.4 : "	: Building near old wharf	: C.&G.S.
Apponaug	: 16.1 : Open :	On bank near R.R. Sta., Greenwich Bay	: "
East Greenwich	: 15.7 : Still:	In Yacht Club, Greenwich Cove	: "
Wickford	: 13.6 : "	: In Reynolds home, Wickford Harbor	: "
Plum Beach	: 14.5 : Open :	Debris, Hazards Quarry	: U.S.E.
Pettaquamocutt River	: 18.5 : "	: Debris and erosion in the narrows	: "
Narragansett	: 16.8 : "	: Debris and erosion, lower pier	: R. I.
Point Judith	: 22.1 : Still:	In whistle house, Lighthouse Service	: U.S.E.
Point Judith	: 14.5 : Open :	Debris 1 mile north of point	: "
Matunuck	: 13.7 : Still:	In house, Matunuck Beach	: "
Charlestown	: 13.4 : "	: In garage, SW end Charlestown Pond	: "
Charlestown	: 14.2 : Open :	Grass contour, SW end " "	: "
Weekapaug	: 11.9 : "	: Debris and sand rear Post Office	: "
Watch Hill	: 12.4 : Still:	Inside Fire Station, Watch Hill Cove	: "
Watch Hill	: 11.6 : "	: Notch on building " " "	: "
Westerly	: 12.2 : "	: Inside garage, Pawcatuck River	: C.&G.S.

CONNECTICUT

Stonington	: 11.0 : Still:	In R.R. switch tower, near station	: C.&G.S.
Mystic	: 10.8 : "	: In cellar, near Murphy Point	: "
Noank	: 10.3 : Open :	Debris on Mystic River	: "
Groton	: 11.2 : Still:	Electric Boat Co. bldg.	: "
New London	: 11.4 : Open :	Debris on fence, Esso Co., Shaws Cove	: "
New London	: 11.5 : Still:	Custom House Wharf - in shop	: "
New London	: 11.2 : "	: Inside Dumonts Marine Station - City	: "
	: :	: Wharf	: "
New London	: 11.6 : Open :	On steps NY, NH, & H. R.R. Station	: "
New London	: 11.5 : "	: On pile, Coast Guard Academy Pier	: "
New London	: 11.3 : "	: In Merritt, Chapman & Scott Co. yard	: "
Saybrook	: 13.4 : Still:	In light, outer breakwater	: "
Branford	: 12.0 : "	: In shed, Branford Coal & Lumber Co.	: U.S.E.
Branford	: 11.8 : "	: In Branford Yacht Club	: "
New Haven	: 13.8 : Open :	Debris Fort Hall Park	: "
New Haven	: 13.4 : Still:	In keeper's house, Lighthouse Point	: "
New Haven	: 11.9 : "	: In machine shop, Tomlinson Aqueduct	: "
West Haven	: 16.6 : Open :	On threshold Wilcox Dance Pavilion,	: "
	: :	: Savin Rock	: "
West Haven	: 13.9 : "	: On house rear " " "	: "
	: :	: Savin Rock	: "
Bridgeport	: 13.8 : Still:	Bridgeport Towing Co. office, Strat-	: "
	: :	: ford Bridge	: "

<u>Location</u>	<u>Elev. Still above or M.L.W. Open in ft. Water</u>	<u>Remarks</u>	<u>Bench Mark</u>
Bridgeport	: 13.7 : Open	: Baumworth Building	: U.S.E.
Bridgeport	: 12.8 : "	: Door Fayerweather Yacht Club,	:
	: : "	: Black Rock Harbor	: C.&G.S.
Southport	: 13.4 : "	: On steps Pequot Yacht Club	: "
South Norwalk	: 11.6 : "	: On building foundation east of	:
	: : "	: river	: U.S.E.
Rowayton	: 14.3 : "	: On house, Five-Mile River	: "
Stamford	: 14.7 : "	: On tank, Flemmings Coal Dock	: C.&G.S.
Stamford	: 15.6 : "	: On lawn, Stamford Yacht Club	: "
Coscob	: 15.3 : "	: On shed NY, NH, & H. power plant	: U.S.E.
Greenwich	: 15.0 : "	: On boathouse wall, Indian Harbor:	:
	: : "	: Yacht Club	: "

16. Wave Action. - The unusually high speed of translation of the hurricane in higher latitudes prevented the heavy swell and surf from giving appreciable warning of the storm's approach. However, the Ditch Plain Coast Guard Station at Montauk, Long Island, reported mounting surf on September 20th with moderate to strong breezes. At 7 p.m. the surf was reported as very high while the breeze was moderate. Watch Hill Coast Guard Station reported high surf all day on the 20th, with moderate to fresh breezes.

Observations of wave heights and intervals were made against great difficulties. Visibility was poor due to flying spray. Maximum waves occurred at time of great emergency, when attention was being given to saving of life and property. Necessity of flight by persons ordinarily able and qualified to observe wave phenomena renders reported data meager and unreliable. Heights for locations with similar degrees of exposure agree fairly well. The reported intervals between waves probably vary to a greater degree than was actually the case. Reported heights and intervals from the Lighthouse Service, Coast Guard, and other sources are listed in Table 3 following:

TABLE 3

WAVE DATA - SEPTEMBER 21, 1938

<u>Location</u>	<u>Max. Ht. of Wave (Foot)</u>	<u>Interval Between Waves</u>	<u>Max. Height of Effect Above M. H. W.</u>	<u>Remarks</u>
<u>Nantucket Sound</u>				
Handkerchief Lightship	15	--	--	Short choppy seas.
Great Point, Nantucket	6	--	--	
Cape Pogo Light	40	--	--	10' waves in Cape Pogo Pond.
Edgartown Harbor Light	--	--	--	Little surf-very strong current; 400 to 1200 lb. break-water stones washed 8 to 10 feet; undermined foundations of light.
<u>Vineyard Sound</u>				
West Chop Light	5	12 sec.	--	
Nobska Point Light	15	--	10-15'	Moved stones up to 1500 lbs.
Tarpaulin Cove Light	4	45 sec.	8'	Washed away stone wall.
Gay Head Light	25	2 min.	15-20'	Erosion of cliffs.
Vineyard Sound Lightship	25	10 sec.	20'	
<u>Buzzards Bay</u>				
Cuttyhunk Light	20	15 sec.	15'	Moved 3-ton stones 100 ft. from M.H.W.
Wings Neck Light (Wonaumot Neck)	8	30 sec.	29'	Sand, gravel and rocks washed over reservation. 400 lb. rock lifted to 12' above M.H.W. Rocks and water broke windows 29' above M.H.W.

<u>Location</u>	<u>Max. Ht. of Wave (Foot)</u>	<u>Interval Between Waves</u>	<u>Max. Height of Effect Above M. H. W.</u>	<u>Remarks</u>
Butlor Flats Light	14	1-1/2 min.	16'	
Dumpling Rocks Light	--	--	--	Deposited stones from breakwater in first floor-waves broke over tower about 50' high.
Now Bedford Harbor	4	--	15'	Choppy-irregular seas.
Westport, Mass.	8	--	20'	Waves appeared flattened by wind. Surf carried buildings across low land at speed of about 20 M.P.H.
<u>Narragansett Bay</u>				
Sakonnet Point	--	less than 1 min.	52'	Shell fish and gravel thrown through window and 3/4" stair landing plates broken at height of 52 ft.
Fall River	4	5 sec.	15'	Choppy waves, many eddies and whirlpools extremely strong ebb currents before water dropped.
Musselbed Light Station	8	2 min.	15'	Large stones washed away.
Brenton Point Coast Guard	30	20 sec.	--	Entire lower story wrecked by waves.
Castle Hill Light	15	3 min.	45'	150 lb. stones washed up on cliff to 50' above L.W. Broke glass in tower 43' high

<u>Location</u>	<u>Max. Ht. of Wave (Feet)</u>	<u>Interval Between Waves</u>	<u>Max. Height of Effect Above M. H. W.</u>	<u>Remarks</u>
Newport Harbor Light	20	--	20'	Large rocks carried 300 to 500 ft.
Rose Island Light	5-10	--	10'	Large stones (over 200 lbs.) thrown up to 10' above M.H.W.
Gull Rocks Light	5	15 min.	12'	Current running about 20 M.P.H.
Gould Island Light	4	8-10 sec.	12'	
Prudence Island Light	10	30 sec.	20'	Cement walk and buildings washed away.
Hog Island Light	20	4-5 min.	20'	Stones up to one ton moved.
Conimicut Light	15	--	18'	Seaweed and debris washed into second floor windows at 22 ft. above L.W.
Sabine Point Light	10	--	30'	4-ton stones moved more than 5' above M.H.W.
Pomham Rocks Light	20	30-40 sec.	20'	30' crest to trough 200' apart like long lines of tents reaching across river. 2 cu. yd. stones moved.
Beavertail Light	30	--	27'	One ton stone washed up to 27'.
Warwick Light	12	Very Short	35'	25-30 lb. stones thrown 15-18' above sea wall, surf breaking almost continually.

<u>Location</u>	<u>Max. Ht. of Wave (Feet)</u>	<u>Interval Between Waves</u>	<u>Max. Height of Effect Above M. H. W.</u>	<u>Remarks</u>
<u>Block Island Sound</u>				
Point Judith Light	20	1 min.	25'	2-ton stones deposited 15' above M.H.W.
Watch Hill Light	40	Short	60'	40-lb. stones thrown in windows 18' above H.W. 4-5 ton stones from seawall strown around beach.
Watch Hill	30	--	60'	Stones up to 30 lbs. washed up over 60' above M.H.W.
<u>Fishers Island Sound</u>				
Latimer Reef Light	16	30 sec.	22'	4-5 ton stones lifted 3-4' and carried 15' by force of waves.
North Dumpling Light	20-25	5-8 sec.	25'	3-4 ton stones washed up to 6' above H.W.
Race Rock Light	40	--	20'	5-ton stones carried 50'.
East Harbor, Fishers Island Coast Guard	10	--	--	
<u>Long Island Sound</u>				
Electric Boat Co., Groton	--	15 sec.	--	18" cross chop lashed into spray by wind over a heavy ground swell.
New London	10	10 sec.	10'	At State Pier.
New London Sub. Base, USN	3	--		Short choppy.

<u>Location</u>	Max. Ht. of Wave (Feet)	Interval Between Waves	Max. Height of Effect Above M. H. W.	<u>Remarks</u>
Little Gull Island Light	30-35	--	33'	2-1/2-ton stone at 5' above M.H.W. moved 10'. 1-ton stone at 16' above M.H.W. overturned, windows broken at height of 33'.
Orient Point Light	18-20	Short	25'	3-10-ton stones washed from breakwater.
Saybrook Breakwater Light	12	30-90 sec.	21.7'	2-4-ton stones washed 75'.
Falknor Island Light	10	30 sec.	10'	Stones up to 5 tons washed up to 4' above M.H.W.
New Haven Harbor	5	--	9'	
S. W. Ledge Light	15	1 min.	25'	Large stones washed from breakwater. Section plate ripped from galley deck above M.H.W.
Bridgeport Harbor (Ponfield Reef Light)	15	1 min.	20'	Moved stones weighing 1 to 5 tons 10 to 15 ft.
Pleasure Beach, Bridgeport	5	5 sec.	10'	
Stratford Shoal Light	--	--	30'	Swept deck of light at 30 ft. elevation.
Norwalk-Greens Lodge Light	25	--	--	1/2-ton stones moved.
Stamford Harbor	2	--	10'	
Great Captain Island Light	6	20-30 sec.	20'	Stones broke windows 20 ft. above M.H.W.

The greatest storm seas in the district were thirty or more feet in height and occurred in exposed locations in Block Island Sound, notably Sakonnet Point, Brenton Point, Point Judith and Watch Hill. All observers

agree independently that the heavy battering seas were at least thirty feet from crest to trough. The Coast Guard at Brenton Point timed them at three per minute. At other exposed locations, such as Cape Poge on Nantucket Sound, Race Rock in Fishers Island Sound and Little Gull Island, Long Island Sound, similar estimated wave heights were reported. Practically all other observers in exposed locations in Nantucket and Vineyard Sounds, Buzzards and Narragansett Bays, Fishers and Long Island Sounds report waves of twenty feet or more. In less exposed parts of Narragansett Bay and Buzzards Bay, ten-foot waves similar to offshore waves during ordinary storms were reported. Waves in harbors generally were up to five feet in height, and extremely choppy, often occurring as a vicious cross chop quartering a heavier ground swell and appearing crowded and uneven, not breaking to their full height as the tops were blown off in spume. Along harbor waterfronts and at the mouth of rivers (Warren, Thames, Providence, etc.) observers describe the water as blown flat by the force of wind.

Some observers at exposed locations stated that the tide rose as a series of waves and that the water did not recede after each wave. Each successive wave added to the height of solid water. This probably accounts for the greater heights of high water at Sakonnet and Brenton Points and at Point Judith. At these locations the incessant wind pressure did not permit the water to retreat completely in the intervals between waves.

On reaching shallower water, huge waves broke on the beach against dunes, walls and buildings. Structures exposed to the violence of these waves near their breaking point were crushed like paper, as illustrated by Plate 23. The first floor of the Brenton Point Coast Guard Station, a

strongly framed building on a substantial foundation (Plate 18), was entirely cleaned out, leaving only the walls. Less strongly built and well founded structures did not survive this attack. Dunes up to 25 feet in height disappeared as the waves broke over them. (See Plate 6). Some low seawalls, such as that at Watch Hill shown on Plate 2, survived because they were completely submerged and protected from the most violent attack. Waves striking vertical surfaces were thrown to great heights. Instances where debris was thrown high causing damage to light towers and buildings are cited in the foregoing table. Seaweed and shellfish were found in upper stories of buildings up to 50 feet above low water. The effect of wave action at Watch Hill in Westerly, Rhode Island, is of particular interest. The large residence shown on Plate 2 is located at the top of a steep bluff at an elevation of about sixty-five feet, and seventy feet in back of a seawall about 10 feet above mean low water. Persons in the house at the time state that solid sheets of water struck the house with great violence. Windows and doors were broken, and water entered the house sufficient to float large pieces of furniture. After the storm subsided, sand, small stones and seaweed were about one foot deep on the main floor of the house.

1938 HURRICANE - EFFECTS AND LOSSES

17. Loss of Life. - The number of lives lost in this District totals over 400. Some of the deaths, such as those caused by falling buildings and flying debris, were a direct result of the high winds. The loss of life by drowning in the inundated area was by far the greatest. Instances are reported in which victims drove to the beaches to watch the surf and were trapped in their automobiles by the sudden rise of water. Four drownings occurred in the City of Providence, two of which were in the heart of the business section. Rescues of persons marooned in cars stalled by water in the center of the city were numerous. The deaths resulting from the hurricane wave in the three coastal states of this District were about as follows: Southeastern Massachusetts, 100, Rhode Island, 200, and Connecticut, 100. The Red Cross statistics for New York and New England include those which were a direct result of the wind, and are as follows:

	<u>Deaths</u>	<u>Injuries</u>
New York	60	31
Connecticut	97	109
Rhode Island	207	204
Massachusetts	117	331
New Hampshire	12	32
Vermont	1	1
Totals	494	708

18. Effect on Shore Line and Beaches. - Practically the entire length of the shore line in this District suffered some change as a result of the storm attack. The glaciated material forming this coastal region offers varying degrees of resistance to erosion. The outlying islands of Nantucket, Marthas Vineyard, and Block Island, with the southern

part of Long Island terminating at Montauk Point, constitute the earlier terminal moraine known as the Ronkonkoma moraine. Part of the outwash plain of this moraine remains in evidence in the southern parts of the islands of Nantucket and Marthas Vineyard. The later, or Harbor Hill moraine, extends along the southern arm of Cape Cod, through the Elizabeth Islands, along the south shore of Rhode Island west of Narragansett Bay, through Fishers Island to Orient Point on the northern side of Long Island. The outwash plain of this moraine appears on the western part of the south shore of Cape Cod. In Rhode Island little of the outwash plain remains above sea level. Since deposition these morainal and outwash plain materials have been eroded, supplying material from which bars, spits and tombolos have formed in many locations. Where loose materials were exposed to the most severe attack, such as at Nantucket, Marthas Vineyard, and the south shore of Rhode Island, the shore lines present the typical smooth outline of a coast approaching maturity. Where the material is more resistant and less exposed, as in Buzzards Bay and Long Island Sound, the typical irregular outline of a shore line of submergence in a youthful stage of development predominates. The unconsolidated materials of the glacial deposits and wave-built forms offered little resistance to the wave attack of the hurricane. Even the headlands, composed of hard-packed till and clay with boulders, suffered more erosion in a few hours than would occur in years of normal attack.

The erosive action of waves generated by the gale was not confined to the outer shore and bays. A causeway crossing and dividing the Providence water supply reservoir at Scituate, Rhode Island, was swept away for a length of 326 feet, and damaged for about 400 feet further. The

side slopes of the causeway were about 1 on 1-1/2 to 2, and were covered with a dumped stone fill about 1 to 1-1/2 feet thick. The causeway, which was of sand and gravel fill with top width of about 30 feet, was scoured out to a depth of 30 to 40 feet below road grade. The water surface elevation on the day of the hurricane was about 10 feet below road grade. The fetch from the southeast and south is about 2-1/2 miles. Reconstruction of the causeway will probably cost about \$25,000. A small concrete bridge adjoining the demolished section was unharmed as the abutments extend to original river bottom, a depth of about 60 feet.

The extreme eastern section of the District did not experience severe attack. At Chatham on the ocean side of Cape Cod, at Monomoy Point, and on the eastern side of Nantucket Island no abnormal erosion occurred. These locations were protected from the swells that approached from the south and west from the center of wave violence in Block Island Sound. The attack was felt on the southwestern side of Nantucket, on Marthas Vineyard, and after passing through Muskeget Channel reached the south shore of Cape Cod. Available information on the storm's effect on shore line and beaches follows. Reported distances of erosion cannot be considered actual recession of high water line, as observers in many cases were unfamiliar with former conditions. Wave attack was at a high level. Reported distances would probably be more accurately regarded as the maximum distances at which the erosive action of the attack was evident.

19. Maddaket, Nantucket, Massachusetts. - This beach consists of bars across the mouths of several small ponds and a sand spit known as Smith Point extending northwestward. The formation is entirely sand from the outwash plain of the terminal moraine. Erosion of dunes and a portion of the road near the beach was reported.

20. Chatham, Massachusetts. - Harding Beach is a sand spit extending southeastward from a high bluff of unconsolidated glacial drift. The bluff was undercut in some places and small slides occurred. Additional sand appears to have been deposited on the beach above the elevation of mean high water.

21. Harwich, Massachusetts. - The beach at Witchmere Harbor suffered little change. Some erosion was in evidence east of the harbor entrance.

22. Yarmouth, Massachusetts. - Exposed fast land of the moraine at Parkers Neck receded about five feet in some places. The eroded sand accumulated on the west sides of a series of low stone groins. The beach was higher especially at the inner ends of the groins. Formerly an island, Point Gammon had been connected with the mainland by a low tombolo. The beach on the eastern side of the point appears higher near normal high water mark, especially on the south side of the small wooden groins.

23. Point Gammon to Nobska Point, Massachusetts. - This area is primarily the outwash plain of the Harbor Hill moraine, and is composed largely of sand and gravel. The western part of this area has many narrow bays, some partly, others entirely closed by baymouth bars. At Menauhant, breaching of the low narrow barrier beach and washing of the material into the pond were reported. Probably the shelter provided by Marthas Vineyard considerably lessened the violence of the attack in this area. Nobska Point, however, is exposed to attack from the southwest through Vineyard Sound. A shore line recession of 10 to 50 feet near the Light Station is reported. Stones and boulders weighing up to 1,500

pounds were moved. Heavy erosion of the headland at Falmouth Heights was reported.

24. Marthas Vineyard, Massachusetts. - The south shore line is very similar to that from Nobska Point to Point Gammon. The original shore line was deeply indented by many narrow embayments, practically all of which had been closed by a series of baymouth bars. The barrier beaches were overtopped, but no permanent breaches were reported. Erosion of cliffs at Gay Head was reported. The keeper at Cape Poge Light reports about 20 feet of land washed away. A bar in Monomsha Pond was cut through.

25. Cuttyhunk Island, Massachusetts. - The tombolo at the eastern end of the island was breached as shown on Plate 7 to slightly below mean low water elevation, with a width of over 300 feet between high water lines. This breach has been closed artificially by a dike 785 feet in length, with top width of 80 feet at an elevation of 7 feet above mean low water. This is approximately the elevation of the barrier before the hurricane.

26. Woods Hole, Massachusetts. - A low narrow barrier connecting Long Neck with the mainland was overtopped. Due to the greater height of the wave in Buzzards Bay than in Vineyard Sound the wash was from the north. A gully was scoured on the south side and some damage was done to the highway across the beach.

27. East Shore of Buzzards Bay. - This shore line was under violent attack. The most severe erosion was reported on Nyes Neck at North Falmouth. At Wings Neck Light on Wenaumet Neck, banks were reported cut away from 12 to 20 feet.

28. North Shore of Buzzards Bay. - The Lighthouse Service reports erosion of 10 to 100 feet at all land stations in Buzzards Bay. The exposed banks of islands suffered heavy erosion. Headlands were severely eroded. Reported erosion is as follows: Sconticut Point - heavy, Clark Point - 60 feet, Ricketsons Point - 40 feet, Round Hill - east side 40 feet - south side 200 feet, Salters Point - 80 feet, Mishaum Point - 100 to 120 feet, Potomska and Barneys Joy Point - deeply eroded.

29. Horse Neck Beach, Westport, Massachusetts. - The beaches at this location consist of baymouth bars in cusped form extending east and west to form a partially completed Y-tombolo, connecting with a former island known as Gooseberry Neck. The beach east of Gooseberry Neck is low and comparatively narrow and about one mile in length. Considerable shingle is in evidence on this beach. This beach and about one mile of the west beach were closely built with summer residences, practically all of which were completely demolished by the hurricane tide and surf. There was no opening to the bay through East Beach immediately prior to the hurricane. Two breaks cut through this beach by the storm have been filled artificially. The tombolo to Gooseberry Neck had been developed naturally only to about low water elevation. About ten years ago a road was built on a solid causeway to develop the island. Much of the road and causeway were destroyed. Horse Neck Beach proper, to the west of Gooseberry Neck, is about three miles long and over one-half mile in width at places. Most of the width was covered with a series of high dunes. The entire area consists of fine sand except that there is some shingle immediately adjacent to the Neck. During the hurricane the seaward dunes were severely eroded. In some sections the seaward row disappeared entirely

as illustrated by Plate 6, and erosion of the second row occurred. Horse Neck Point at the western end of the beach was washed over for a length of about one-quarter mile and the dunes were levelled. The foreshore suffered little if any change, except at the Point. Here a jetty had caused accretion amounting to several hundred feet. The hurricane wave cut behind the jetty and moved the high water line approximately to its former location, and extended the Point somewhat to the westward.

30. Acoaxet, Westport, Massachusetts. - This area consists of three headlands with many boulders and two baymouth bars. The eastern end of the east headland, except a large rocky point known as the Knubblo, was washed over. The cliff of glacial debris, formerly 12 to 15 feet high, was cut down almost to mean high water elevation as shown on Plate 3, just short of opening a new entrance about 250 feet wide to Westport River. The eastern half of the section was built up with high class residences. Practically all those on the bar were demolished.

31. Little Compton, Rhode Island. - Tunipus Beach was a fine sandy baymouth bar beach with berm covered largely with shingle. The foreshore appeared steeper and was covered with shingle from the adjacent headland. The headland at Brigg's Point was reported cut back 80 to 100 feet. Brigg's Beach, a baymouth bar, was reported flatter than before with more stones. The headland at Warren Point was reported cut back 100 to 120 feet. Warrens Beach, a crescent midbay bar well protected by rocky headlands, had its foreshore practically unchanged. Its dunes about 20 feet high and 300 feet long were washed away. The headland at Sakomnet Point experienced violent attack. Exposed ledge was unchanged, but heavy glacial clays and boulders were stripped off and additional ledge uncovered. (See Plate 13). The bayside beach at Church Cove was reported quite stony, and

Church Point headland was reported cut back about 60 feet. Shore line in the vicinity of Brown Point was reported cut back about 150 feet, leaving rocky beach and exposed glacial clays.

32. Tiverton, Rhode Island. - Dunes on Windmill Hill Beach, a bay-mouth bar, were levelled, and stones were strewn over the beach. The headland, High Hill Point, was eroded severely. The connection between Fogland Point and the mainland is probably a tombolo. High sand dunes on this beach were levelled. Sapowet Point, probably a cusped bar, is reported cut back 150 to 180 feet. The channel to the enclosed pond was shifted. Exposed fast land at Nannaquaket was reported cut back 40 feet.

33. Fall River, Massachusetts. - The beach at the south end of the city was eroded 40 feet.

34. Somerset, Massachusetts. - At Breeds Cove erosion of 20 to 30 feet was reported. The high bank of the Brayton Point headland was cut back 120 to 150 feet, leaving houses hanging over the edge.

35. Swansea, Massachusetts. - On the east side of the Gardners Neck headland the shingle beach suffered little change. The bank of unconsolidated glacial till above mean high water was cut back 20 or 30 feet. Seawalls and a flat terrace on the south side of Gardners Neck apparently afforded protection from the direct sweep across Mount Hope Bay, as it was reported that no noticeable erosion of the shore line occurred. The Ocean Grove beach is a winged headland. The foreshore was in general unchanged, except in front of the headland where it was built up to 1 to 2 feet in front of some seawalls. The headland was closely built with houses behind a heterogeneous assortment of seawalls, which generally afforded sufficient protection so that the houses at higher eleva-

tions were little harmed. The walls were not high enough to prevent removal of the loose glacial drift between the walls and the houses. Where the walls were structurally weak the top of the cliff retreated as much as 50 feet, leaving the houses overhanging the beach as shown on Plate 5. The spit to the east of the headland was little changed, probably due to the protection afforded by Gardners Neck. The spit to the west was low and closely built with summer houses on piles. The houses were completely removed by the hurricane tide, and the berm was lowered so that spring tides might flow over it at places. A railroad embankment on the western portion of the spit was almost entirely washed away.

36. Warren, Rhode Island. - Touisset Neck is a headland of unconsolidated glacial till. The headland beach is sandy. A short spit at the west side of the headland extends into Kickamuit River. The foreshore suffered little or no change. The top of the bluff retreated between 10 and 25 feet.

37. Bristol, Rhode Island. - The foreshore of the shingle bayside beach north of Mount Hope Bridge on the east side of the point was practically unchanged. The top of the berm retreated 10 to 20 feet. The Popasquash Neck headland was severely eroded.

38. Portsmouth, Rhode Island. - At McCurry Point, a foreland, the shore line was reported cut back 50 feet. The Sandy Point foreland was reported eroded and covered with stones about 6 inches in diameter. The Island Park section appears to be a cusped bar or foreland, or possibly a tombolo. The beach along the south side was closely built with summer residences, practically all of which were demolished. The flat sandy beach appeared to be reduced in level about one foot.

39. Middletown, Rhode Island. - Sachuest (also known as Second Beach) and Third Beaches appear to constitute a double tombolo, lying between sturdy headlands. The storm tide washed across the low part of the tombolo. The foreshores were not materially changed. Buildings were demolished or washed away. The berm of Sachuest Beach was lowered and the road was washed out. The dike around Gardiner Pond, north of Sachuest Beach, was washed out in several places. This pond is used for water supply. Around the Easton Point headland erosion up to 100 feet into the cliff was reported.

40. Newport, Rhode Island. - Newport Beach (also known as First and Eastons Beach) is a midbay bar between two rugged headlands. It was developed with a boardwalk and amusement structures, all but one of which were demolished. The foreshore was probably little affected. At the west end where the beach joined the headland a heavy masonry seawall was demolished, and the top of the cliff retreated about 60 feet, carrying with it a considerable portion of the highway as may be seen on Plate 13. The dike around a water supply reservoir, north of the beach, was washed away in two places about 150 feet long. Cliff Walk, a well known promenade, built into the side of the headland cliff from the west end of Newport Beach to Lands End, was reported almost a total loss. The erosion of the cliff was severe. West of Lands End lie two midbay bar beaches, Baileys, and Viking or Hazards Beaches, between rugged headlands. Buildings on both beaches were destroyed or damaged so as to necessitate replacement. Sand from these beaches was washed into the ponds behind them. The height of foreshore and berm was generally reduced. From Viking Beach to west of Brenton Point the headland, composed largely of resistant clay

and stones on lodge rock, was severely eroded. The top of the bank retreated distances up to 100 feet, extending across Ten Milo Drive in places, as shown on Plate 3.

41. Barrington, Rhode Island. - The shore line of Barrington consists largely of high fast land with few wave built features. Inspection revealed little change in the foreshore. Upper banks were in general eroded even behind seawalls. This erosion in some places exposed a hard clay substratum which resisted wave attack.

42. East Providence, Rhode Island. - North of Bullock Point erosion of over 100 feet in some places was reported.

43. Cranston, Rhode Island. - At Edgewood slight erosion was evident on banks up to 150 feet from high water line.

44. Warwick, Rhode Island. - The bluff at the rear of Gaspee Point, a cusped bar, was reported cut back about 10 or 12 feet. The shore line and beach at Conimicut Point probably changed little. Practically all buildings on this foreland were demolished or badly damaged. Erosion on Warwick Neck is shown on Plate 4. Erosion was evident on the beaches along the north side of Greenwich Bay.

45. North Kingstown, Rhode Island. - North of Allen Harbor and north of Quonset Point evidence of erosion 50 feet back of the high water line was reported. At Quonset Point erosion of 25 to 75 feet was reported. At Poplar Point erosion to a distance of 20 feet undermined two houses. Erosion was severe at Cold Spring Beach. Greenes Point, Plum Beach and Caseys Point are cusped bars. Some erosion was evident in this stretch. At Saunderstown erosion is evident for 50 feet back from high water line.

46. Narragansett, Rhode Island. - Bommet Point, a rugged headland,

was eroded slightly. Wesquage Beach, or Bonnet Shores, is a crescent midbay bar. The hurricane tide washed over this bar, lowering the foreshore and berm and severely eroding the dunes as shown on Plate 5. The Dunes Club, on a broad baymouth bar at the entrance to Pottaquamscutt River, lost the sand dunes which were its distinctive topographical feature. The foreshore was reduced in height by 3 to 4 feet and the sand was deposited inshore to about the same depth as illustrated by Plate 9. At Narragansett Pier the shingle and cobble beach probably changed little. The bluff, although protected somewhat by a heavy masonry wall, was badly eroded. In some parts the top of the bluff was cut back to about the middle of the road as shown on Plates 4 and 15. At the bayside beach at Scarborough, the foreshore was lowered 1 to 2 feet, and some shingle was washed onto the beach. The headland at Point Judith is composed largely of clay and boulders. The beach at the foot of the bluff is composed of boulders and cobbles. It suffered little change. The face of the bluff was eroded up to 25 feet in spite of being hard-packed clay. The low seawall shown on Plate 15 apparently provided little protection. Galilee is a fishing and resort village on a baymouth bar between Point Judith and the entrance to Point Judith Pond. A ridge of sand dunes ran almost the length of the bar. Most of the dunes were washed away, the sand being deposited on the road and marshes in the rear. One section of dunes survived, probably due to the protection afforded by the Point Judith breakwaters. The front face of this section was severely eroded. Some cottages were undermined and toppled forward toward the beach. The shore end of the east jetty at the entrance to Point Judith Pond was breached, but natural sand movement closed the opening within a few weeks, as shown on Plate 16.

47. South Kingstown, Rhode Island. - At Jerusalem on the continuation of the bar west of the inlet conditions were similar to those east of the inlet. Part of the dunes remain near the inlet probably due to the protection of the breakwater. A high tide breach through the bar was reported. The Matunuck and Green Hill headlands resisted the attack well. The intervening baymouth bars were swept clear of buildings.

48. Charlostown, Rhode Island. - Charlostown Beach is a baymouth bar between the Green Hill and Quonochontaug headlands. Large sand dunes formerly existed on this beach. The beach was closely built with summer residences, not one of which remains. The wreckage was almost entirely washed to the north side of the ponds. The foreshore appears to have been lowered several feet. The sand was deposited in the marsh area along the ponds. The dunes were levelled off and the sand carried into the ponds. About 20 feet of erosion was reported at the Quonochontaug headland.

49. Westerly, Rhode Island. - The Weekapaug Point (also known as Noyes Point) headland was eroded about 25 feet, although composed of clay and boulder till. The baymouth bar extending eastward to Quonochontaug was breached as shown on Plate 7. An opening about 3 feet deep and 100 feet wide shoaled rapidly by natural sand movement. The baymouth bar west of Weekapaug Point is known as Misquamicut Beach. It had a ridge of high dunes which was severely eroded and breached in some places. A new inlet was washed through about the middle of this beach. It was recently reported that a temporary road across this inlet had been washed away, and that the gap was about 50 feet wide and 20 feet deep in some places. At Watch Hill the bluff of unconsolidated glacial drift over

50 feet high, shown on Plate 2, was reported cut back 30 to 40 feet, although the low seawall in front was unharmed. It is reported that 15,000 tons of stone were dumped on this bank to prevent future erosion. The tombolo and spit known as Napatree Beach and Sandy Point, respectively, were severely eroded. These barriers were breached in several places, as shown on Plate 8. The one just west of Watch Hill Point was about 150 feet wide and 2 to 3 feet deep at mean low water. It has been closed artificially. The foreshore level has been lowered and the dunes have been levelled. The sand was deposited on the road and in Little Narragansett Bay in the rear of the barrier.

50. North Shore Fishers Island Sound. - Probably due to the protection afforded by Fishers Island, erosion was less severe in this area. Erosion was reported as follows: At Noank, Connecticut - 10 feet, Groton Long Point - 10 to 15 feet, Avery Point - 15 feet. Railway fills at Poquonock River were eroded. The beach on the tombolo west of Groton Long Point was covered with coarse gravel.

51. Fishers Island, etc., New York. - Some erosion was reported on Fishers Island and on Plum Island. Approximately one-third of the land area, or about six acres of Great Gull Island was lost by erosion. Much of the west side of the island on which North Dumpling Light is located was washed away. At the Little Gull Island Light the elevation of the land was lowered several feet.

52. New London, Connecticut. - Ocean Beach appears to be the remains of a Y-tombolo. The island has wasted away, only a few rocks offshore indicating its probable former location. It was reported that this beach was lowered 6 feet for a width of 40 feet and length of one-half mile.

Destruction of buildings on this beach is shown on Plato 26.

53. East Lyme, Connecticut. - Black Point is a prominent headland of glacial till. The top of the bluff retreated as much as 15 feet. The foreshore of cobbles was probably little affected.

54. Old Lyme, Connecticut. - Hawks Nest Beach is a headland beach and baymouth bar about midway between Hatchett Point and the mouth of the Connecticut River. The low headland is of fine material and is little different than the bar in appearance. Almost all of the houses on this beach were destroyed, as shown on Plato 26. The berm was reduced in height. The foreshore was cut down along the central portion of the beach. A fill 2 to 3 feet deep was deposited in the rear of the former location of the houses. A low sand dune was washed down to an elevation approximately the same as that of the surrounding area. Sound View Creek was cut deeper and to a high water width of 15 to 20 feet. A small wash through the narrow section of the beach occurred, but its bottom was above ordinary high water.

55. Milford, Connecticut. - The highest cliffs in unconsolidated material to be found on the Connecticut coast occur in Milford. At Morningside, northeast of Pond Point, a cliff eroded in glacial till reaches a height of 40 feet. The beach is shingle and boulders. The foreshore was lowered about one foot. Bay View and Point Beaches are on a bayhead or midbay bar, fronting marshland, between the Pond Point and Welch's Point headlands. The headlands have numerous boulders and the beaches are largely of shingle and cobbles. The foreshore of the beaches was eroded about one foot and material was deposited to the rear. Gulf Beach is a spit extending northwest from the north side of the Welch's

Point headland. It is composed largely of shingle. Silver Beach is on the easterly side of a cusped bar which is part of a partially completed Y-tombolo. The bar connecting to Charles Island is developed only to a little above low water. The sandy foreshore of Silver Beach was cut down several feet and the sand deposited from 1 to 3 feet deep in the highway to the rear. A steel sheet pile bulkhead along part of the beach was damaged little. Myrtle Beach which connects with the west side of the cusped bar was eroded. The foreshore was cut down about 1 foot and the sand was piled to the rear of the high water line. Walnut and Laurel Beaches are sandy bayside beaches paralleling the upland. Walnut Beach appeared to be about one foot lower. Sand was piled in back of the high water line. Laurel Beach was changed little. The substantial seawall was in good condition. Small groins collected some fill on their west sides. Cedar Beach is at the shoreward section of Milford Point, a large sand spit extending into the mouth of the Housatonic River.

56. Stratford, Connecticut. - The higher land west of Stratford Point was probably an island at one time. The area between it and the mainland is now marsh. Long Beach is a large spit extending westward from the former island. It is reported that the Stratford shore line was cut back 50 feet in some places and in others sand deposits made the beach much higher than before.

57. Westport, Connecticut. - Compo Beach appears to be a sand spit extending southwestward from the Hills Point headland and forming Cedar Point. Three comparative profiles run to the former location of the 10-foot depth contour indicate a deepening of the area by about 2 feet, recession of the high water shore line by 12 to 20 feet and recession of

the low water line by 70 to 130 feet since 1934.

58. Summary. - The hurricane tide and wave action had the general effect of eroding headlands and exposed upland, as illustrated by Plates 2, 3, 4, 5, 13, 14 and 15, especially at elevations of 10 to 20 feet above sea level. Due to the abnormal height of the attack, erosion at lower levels was minor. In general, there was no great change in the position of high and low water lines. Most seawalls being low, the attack passed over them and they did not prevent erosion of the bluffs. Most of the lower sand dunes were washed away, as exemplified by Plate 6. Dunes with elevations of 20 feet or more, especially those covered with vegetation, frequently provided protection to structures at their rear, although their faces generally were cut back. Where dunes had been previously cut down by artificial means, a natural path was provided for the water of the hurricane tide. The breach was widened and the levelling of a considerable length of dune resulted. At some locations the cut was scoured below low water and new inlets resulted, as illustrated by Plates 7 and 8. In some cases local authorities closed the new inlets artificially. In others it appears that nature will eventually rebuild the bars as before. Several have already been closed by natural sand movement. (See Plates 7 and 16). The general effects on sand spits and bars were a reduction in the height of the foreshore and berm, and a widening of the barrier by deposition of the sand on its landward side as shown by Plate 9. The foreshores of some beaches lost as much as four feet of sand.

Damage to beaches as a loss of real estate was not large. In general the shore line did not retreat materially. In some cases bars are wider

than before. Reduction in height of the area immediately behind the high water line results in a loss of market value for this land. The fact that the hurricane proved the danger of occupying coastal land having an elevation of less than 15 or 20 feet above mean high water, has resulted in the greatest loss of market value. This cannot be regarded as a real loss, as this land has always been unsuitable for residential purposes. Beaches for use as recreational areas have not deteriorated materially. A change in use of beaches from residential to recreational would result in increased value of adjacent upland, which would more than offset the loss of market value of beach real estate. Therefore, excluding damage to structures, no monetary value can be assigned to the effect of the hurricane on the shore line and beaches themselves.

59. Effect on Inlets and Channels. - With a few exceptions there was practically no change in existing inlets and channels. At Menomsha Pond, Marthas Vinoyard, Massachusetts, a basin just inside the inlet separated from the main channel by a sand spit was shoaled considerably. This was partially caused by breaching of the spit. The basin has been redredged and the spit restored by the State at a cost of about \$19,000. In Westport Harbor, Massachusetts, the unstable shoals are reported to have shifted, leaving several feet less depth in the main channel than before. No examination has been made. In Providence Harbor, Rhode Island, sediment traps on oyster beds adjacent to the channel indicated average deposition due to the hurricane of about 0.06 inch, or about seventeen times the normal daily rate. Whether the same applied to the channel is immaterial, as the amount involved is so small. Along the Municipal Dock at Field Point where a depth of 30 feet had been secured in 1933, shoaling

averaged almost two feet. It is thought that most of this was due to the hurricane. The volume of dredging required was estimated at 35,750 cubic yards to cost about \$18,000. A considerable volume of eroded material appears to have been deposited in the Providence River above the Point Street Bridge, where the channel had been maintained by the City of Providence. The City estimates that dredging of 170,000 cubic yards to cost about \$80,000 is required to restore a 20-foot depth, not including the slips. This volume is equivalent to a depth of about 7 feet over the area. This area had not been dredged since 1930. Records of previous dredging indicate that a considerable proportion of this shoaling was due to normal deposition. Possibly about one-fourth of the quantity can be ascribed to the hurricane tide. The channel through the entrance to Point Judith Pond, Rhode Island, was reported to have scoured in places to a depth of 18 feet. The depth before the hurricane was about 11 feet. Minor shoaling was reported in certain portions of New London Harbor. The locations cited are the only ones where marked changes in channels as a result of the hurricane have been reported. The loss in this respect totals only about \$50,000, as far as has been determined. Shoaling of slips has been reported in a few places. Loss to oyster beds by sedimentation has also been reported. Two companies reported combined losses of \$125,000 worth of oysters in Narragansett Bay. A loss of \$20,000 worth of oysters at Milford, Connecticut, was reported by one company.

60. Obstructions and Wreck Removal. - Although harbor shore lines were strewn with wrecks and wreckage, comparatively few remained in the channels and were obstructions to navigation. Bridge damage, flooding of operating mechanism, and lack of power caused temporary obstructions to channels. The following is a list of major bridge obstructions that

temporarily interfered with navigation.

<u>Location of Waterway</u>	<u>Remarks</u>
Woods Hole, Mass.	Over Eel Pond
New Bedford, Mass.	New Bedford - Fairhaven Bridge
	Coggeshall Street Bridge
Sakonnet River	Stono Bridge, Tiverton
Providence, R. I.	Point Street Bridge
	India Point Railroad Bridge
	Washington Bridge
	Tunnel Railroad Bridge
	Central or Red Bridge
Mystic, Conn.	Highway Bridge over Mystic River
New London, Conn.	Shaws Cove Railroad Bridge
New Haven, Conn.	Tomlinson Bridge
	Ferry Street Bridge
Bridgeport, Conn.	Johnsons River
	Yellow Mill Pond
	Poquonock River

About thirty-five wrecks and menaces to navigation were removed at a cost of about \$50,000, including government expense. The State of Rhode Island reports the raising of about ninety boats at a cost of about \$3,000. Most of these boats were salvaged.

61. Damage to Shipping and Pleasure Craft. - A large proportion of all boats in the district at the time of the hurricane sustained at least minor damage. Two commercial ships of considerable size were beached in Somerset, Massachusetts. (See Plate 20). One, the oil tanker PHOENIX, was refloated at considerable expense. The other, the freighter NEW HAVEN, was scrapped. Two large barges, shown on Plate 19, blocked a waterfront street in Providence after the water subsided. Cost of re-floating of these barges was estimated at \$3,000. A tug GASPEE was sunk in the fender of the India Point railroad bridge in Providence Harbor, preventing the opening of the draw. (See Plate 11). Part of the stack and pilot house was removed at a cost of about \$250. The tug is a total loss. A 165-foot scow was at the mouth of the Seekonk River in

Providence Harbor. The two Jamestown ferry boats, GOVERNOR CARR and BEAVERTAIL, were beached on Conanicut Island (Jamestown). The GOVERNOR CARR was refloated by the W. P. A. under the supervision of this office at a cost of \$42,096.93. (See Plate 20). The BEAVERTAIL was abandoned. A 275-foot freighter PEQUONNOCK was swept from Newport Harbor and wrecked on Gould Island. A 100-foot sloop was sunk at the Coast Guard Academy dock in New London. The New York District inspection boat MARK BROOKE which was stranded on the tracks of the New York, New Haven and Hartford Railroad at Stonington, Connecticut, was removed and restored to its former condition at a cost of \$24,636.36. The Lighthouse Tender TULIP was across one track of the railroad at New London after the storm, as shown on Plate 19. Damage of \$42,250 to the TULIP was reported.

A large part of the fishing fleets centering at Sakonnet, Newport, Galilee, Block Island, New London, etc., was lost.

Due to boats lost in the hurricane, the registrations of about 500 small power boats were cancelled as follows:

Massachusetts	215
Rhode Island	197
Connecticut	85

In addition the Bridgeport, Connecticut, registration office estimated that at least 100 more registrations would be cancelled, because of the destruction of the boats. Probably the same would be true in Massachusetts and Rhode Island. The total of these boats destroyed would therefore be 700 or 800. Plate 21 illustrates the manner in which pleasure craft were piled up by the storm.

Larger boats, for which documents were cancelled, and others known to be damaged, are listed in the following tabulation:

LOSS TO DOCUMENTED BOATS

<u>Name</u>	<u>Use</u>	<u>Gross Tonnage</u>	<u>Estimated Loss</u>	<u>Estimated Cost of Salvage and Repairs</u>
<u>MASSACHUSETTS</u>				
<u>Buzzards Bay</u>				
Lizzie	Fishing	27	\$ 3,000	--
Alice J. Hathaway	"	89	--	\$ 10,000
Alort	"	47	--	1,500
Katherine F. Saunders	"	91	--	1,000
Ivanhoe	"	52	--	6,500
Isobel Q. Wood	"	37	10,000	--
William Landry	"	30	--	1,000
Luneta II	Pleasure	61	--	4,000
Liliana	"	14	--	4,000
Marilyn	"	23	--	6,000
Clione	"	20	--	2,500
Daiquiri	"	20	--	10,500
Kelbarsam	"	37	--	20,000
Chat Noir	"	35	10,000	--
Palestine	"	68	25,000	--
Gallant	"	29	--	12,000

Fall River Harbor and Taunton River

New Haven	Freighter	2930	--	--
Sogrogansett	Barge	340	20,000	--
Jessie B. Shaw	"	739	10,000	--
Crystal Wave	Coasting Trade	14	5,000	--
Massasoit	Lighter		5,000	--
Phoenix	Tanker	5731	--	100,000

Sub-total - Massachusetts \$ 88,000 \$179,000

RHODE ISLAND

Narragansett Bay and Block Island

Avenger	Pleasure	34	--	5,000
Arrow	"	55	30,000	--
Shadow	"	17	10,000	--
Waljean	"	31	10,000	--
June	"	29	8,000	--
Farwye	"	19	10,000	--
Myrtle E	"	16	800	--
Migrant	"	22	15,000	--
Roberta	"	16	3,000	--

<u>Name</u>	<u>Use</u>	<u>Gross Tonnage</u>	<u>Estimated Loss</u>	<u>Estimated Cost of Salvage and Repairs</u>
<u>RHODE ISLAND</u>				
<u>Narragansett Bay and Block Island</u>				
(continued)				
Blogoe	Pleasure	29	\$ 6,000	--
Spray	"	17	3,000	--
Paladia	"	--	25,000	--
Westport	Passenger	246	--	\$ 3,000
Poquonnock	Freighter	2,930	--	--
Governor Carr	Ferry	412	--	60,000
Beavertail	"	284	100,000	--
Nina	Fishing	17	10,000	--
Placidia	"	52	15,000	--
Hilda & Anna	"	9	5,000	--
Ruth	"	19	7,000	--
Two Friends	"	7	5,000	--
Clayton II	"	11	6,000	--
Albert C	"	43	8,000	--
Emilia D	"	20	6,000	--
Florence F	"	8	5,000	--
Nettie	"	5	3,000	--
Maria	"	32	8,000	--
Perseverance	"	12	300	--
Petrel	"	13	2,500	--
Samoset	"	9	5,000	--
G. H. Church	"	36	--	1,000
Onwego	Coasting Trade	14	6,000	--
Fauna	" "	9	1,000	--
Pal	" "	12	3,500	--
Pilgrim	" "	10	100	--
Dauntless	" "	19	10,000	--
Mabel	" "	9	6,000	--
Nola	" "	18	10,000	--
Lizzie J. Cox	" "	23	1,500	--

Providence Harbor and Seekonk River

Monhegan	Passenger	387	--	2,000
2 Coal Barges	--	--	--	3,000
Gazelle	Freighter	34	10,000	--
Gaspee	Towboat	113	25,000	--
McKinnon Lighter	Lighter	--	--	2,000
Goodrich II	Tank Barge	235	--	10,000

Sub-total - Rhode Island		\$379,700	\$86,000
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<u>Name</u>	<u>Use</u>	<u>Gross Tonnage</u>	<u>Estimated Loss</u>	<u>Estimated Cost of Salvage and Repairs</u>
<u>CONNECTICUT</u>				
<u>Stonington</u>				
Mark Brooke	U.S.E.D.	33	--	\$ 24,636
Marise	Fishing	32	--	1,500
Louise	"	19	\$ 10,000	--

New London Harbor and Thames River

100-ft. Sloop (Unidentified)	Pleasure		5,000	--
Onward	"	28	15,000	--
Konomoc	Water	7	6,000	--
Volunteer	Freight	14	10,000	--
Vitrie	"	765	--	10,000
Marsala	"	2422	--	3,000
Vermont	"	2783	--	25,000
Blue Ribbon	"	423	40,000	--
Malcolm	"	449	--	8,000
Martin Marran	Fishing	308	50,000	--
Rollin E. Mason	"	323	50,000	--
William B. Murray	"	390	50,000	--
Herbert N. Edwards	"	323	50,000	--
General Nathaniel Greene	U.S.A.	340	--	4,660
General Thomas S. Jesup	"	340	--	20,000
Fishers Island	Passenger	862	--	20,000
Tulip	U.S.L.S.	1057	--	42,250
Dobbin	U.S.C.G.		100,000	--
Chase	"		--	5,000

Vicinity of New Haven and Bridgeport

Minnie C	Freight	42	20,000	--
Lou	Pleasure	24	15,000	--
Tu Sabes	"	23	15,000	--
Truelove	"	17	12,000	--
Dauntless	"	27	15,000	--
Coquina	"	21	15,000	--
Lois	Passenger	8	4,000	--
BD 25	Scow		10,000	--
Howard E	Barge	436	40,000	--

Sub-total - Connecticut	\$532,000	\$164,046
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TOTAL	\$999,700	\$429,046
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Based upon reported cancellations of registrations and documents, the estimated cost of salvage and repairs and the estimated value of boats that were a total loss are as follows:

	<u>Salvage and Repairs</u>	<u>Total Losses</u>
Pleasure Craft	\$ 64,000	\$ 600,000
Other Craft	<u>365,000</u>	<u>750,000</u>
TOTAL	\$429,000	\$1,350,000

It is likely that the salvage and repair costs are low, as many boats that required repairs were unreported.

62. Damage to Bridges and Highways. -

a. Massachusetts. - One of the most easterly locations where damage to roads and bridges occurred was at Maddaket near the western extremity of Nantucket Island. The road near the beach was washed away and a small wooden bridge was carried 300 feet inland with a reported loss of \$400. At Tisbury on Marthas Vineyard 2,500 feet of road were washed out. Damage of nearly \$10,000 was estimated. A timber bridge across an arm of Monemsha Pond was swept away. Damage of \$150 to a bridge was reported by the Town of Dennis. At Woods Hole damage to the road across the beach to Long Neck was reported, and a bascule lift bridge across the entrance to Eel Pond was badly damaged. The east abutment was washed out, as shown on Plate 10, and the operating machinery was flooded. On the south shore of Cape Cod bridges were destroyed across the inlet to Great Pond and across the Quostinol River, an arm of Waquoit Bay. On the Buzzards Bay side bridges at West Falmouth Harbor (shown on Plate 10), Pocasset River, Back River, Onset and Wareham were washed away or badly damaged. A concrete bridge across Little River in Dartmouth withstood the flow, but its approaches were washed out for about one-half mile on each side of the river. In Westport, the Hix bridge was washed away and the Westport Point bridge was damaged. At New Bedford, the Fairhaven bridge was not seriously damaged, the Coggeshall Street bridge was temporarily put out of commission and the Wood Street bridge was wrecked. Damages of \$52,591 to walks, roads, curbs and one bridge were reported by New Bedford. At Fall River, the Slados Ferry Bridge, and the Brightman Street bridge, which carries U. S. Route No. 6, were both damaged somewhat. A barge, which was moored between them, went

adrift, striking the Brightman Street bridge on the flood and the Slados Ferry bridge on the ebb. The latter was about to be put in service after having a span knocked out in 1932. The recently completed one leaf lift span was open and vertical during the storm. Its grilled steel floor undoubtedly relieved the wind stress on this open leaf. The Broad Cove highway bridge at the Somerset-Dighton town line was washed away. A bridge at Barneyville in Swansea was destroyed.

b. Rhode Island. - About one mile of road was damaged at Sakonnet Point. Reconstruction will probably cost about \$22,000. In Tiverton the bridges across the entrances to Nonquit and Nannaquaket Ponds and two small bridges at Sapowet Point were washed out. In Newport parts of the section of Ten Mile Drive running along the outer shore east of Brimton Point were washed out, as illustrated by Plate 3. In some places the entire width of the road disappeared. The bituminous macadam paving failed by undercutting as the headland was cut back. It was reported that about 1-1/2 miles of road were washed out around Sachuest and Third Beaches in Middletown. In Bristol, the highway around the north end of the harbor and Colt Drive along Narragansett Bay were damaged. The White Church or Massasoit Avenue bridge across Barrington River in Barrington was washed away with the loss of one life, and damage estimated at about \$30,000. See Plate 10. In Providence, the Point Street Bridge across the Providence River and the Washington and Red Bridges across the Seekonk River were not materially damaged, but flooding of mechanism and lack of electric current caused operating difficulties. The Middle bridge of Pettaquamscutt River between South Kingstown and Narragansett was washed out. The estimated cost of replacement is about \$9,000. At

Narragansett Pier, Ocean Drive was badly damaged, as shown on Plate 4. In the northern section almost the entire width was washed away. Stones from the seawall and boulders from the beach were thrown up on the lawns. Cost of replacement of road and seawall will total about \$90,000. A new timber bridge at Matunuck was swept away, but was taken apart and replaced at a cost of about \$2,500. In Westerly, the concrete bridge across the inlet at Weekapaug was not seriously damaged, but the approaches were eroded. Reported damage to State roads and bridges totals nearly \$200,000.

c. Connecticut. - In Mystic the operating motors of the highway bridge were flooded. A pile trestle bridge at Noank was partly washed away. At Niantic a highway was undermined and washed out in spots. In Old Lyme about three-quarters mile of road along the shore was washed out. Roads were undermined at Saybrook. In Westbrook the shoulders of U. S. Route No. 1 were washed out for about 600 feet just east of the bridge over the Patchogue River. Approximately three miles of town road at the beaches were washed away. A macadam highway along the Clinton shore was badly undermined. In Guilford, the road from Sachem Head to Vineyard Point was partially washed out. Other roads leading to and along shore were undermined. At Branford about 1,000 feet of road were washed out. In New Haven, the Tomlinson Bridge was inundated and its operating motors damaged. The estimated amount of damage was \$10,000. A large oil tank struck a pier of the Ferry Street Bridge, causing considerable damage. Approximately 2,000 feet of State highway were damaged in West Haven. A plate girder highway bridge at Milford had one abutment damaged. In Bridgeport damages to electrical equipment estimated at \$6,500 occurred at the Johnsons River, Yellow Mill Pond and Poquonock River bridges.

About 225 feet of the south approach of the bridge to Pleasure Beach was wrecked, the estimated damages being \$11,000.

63. Summary. - Bridges of modern steel or concrete construction withstood the fury of the attack with little or no damage. Those with elevated superstructures, which allowed vertical clearance above the elevation of high water, were generally unaffected. Where approach embankments restricted estuaries, the fills were frequently eroded and in some cases washed away. The bridges swept away generally had small vertical and horizontal clearance. Pile and timber structures were washed away or heaved and twisted. Flooding of operating mechanism and electrical equipment on drawbridges indicated that more protection should be given these parts in future bridge design. The possibility of installing auxiliary power in case of power failure might be considered. In one instance auxiliary power, although provided for, was inadequate and ineffective due to insufficient maintenance and failure to protect electrical components such as magnetos and wiring from the effect of excessive moisture.

Highways of modern substantial construction were damaged little except where undermined by erosion. Those of oiled sand and gravel were frequently broken up where subjected to wave attack. Obviously the damage estimates submitted include only a small proportion of all damages. Probably about one million dollars would be a reasonable estimate of total damages to roads and bridges by the hurricane wave.

64. Damage to Railroads. - Railroads were damaged at various locations between Cape Cod and New Haven. The New York, New Haven and Hartford with subsidiaries and leased lines serves the coastal region. The

Central Vermont Railway was damaged from New London to Norwich, Connecticut. The Woods Hole branch of the former from Bourne to Falmouth, Massachusetts, had bridges and culverts washed out. Sand was deposited on the roadbed in some locations. Damage was estimated at \$56,000. The Buzzards Bay, Massachusetts, station was flooded and an embankment was washed out. A portion of the bridge of the Cape Cod branch at Wareham, Massachusetts, was swept away. The yard at New Bedford, Massachusetts, was inundated and the freight station was flooded. Embankments on a branch in Somerset and Swansea, Massachusetts, was washed out for about 1/4 mile. This branch was not in use.

In Rhode Island the plate girder bridge across the Warren River and the steel truss bridge over the Barrington River were swept away. These bridges had clearances of 3.8 and 3.0 feet, respectively, above mean high water. In Providence and East Providence at the mouth of the Sookonk River, the wave covered the freight yard, wrecking freight sheds and scattering freight cars and tank cars over a wide area, as shown on Plate 11. There was some damage to the railroad embankment in East Greenwich, Rhode Island, at the south end of the cove off the west side of Greenwich Bay, but service could be maintained on one track. From this point to Stonington, Connecticut, the main line runs inland out of reach of the storm wave.

The Shore Line of the New York, New Haven and Hartford Railroad was washed out at Stonington and Mystic, Connecticut. Five and one-quarter miles of the seaward track and two miles of the other track were washed out in this section. One-third mile of track needed replacement, and the remainder reballasting. The major cause of traffic delay was bridge

damage in Stonington. A 64'-2" plate girder span at Wequetequock Cove, shown on Plate 12, had one abutment washed out and the other one damaged. The vertical clearance of this bridge was 4.2 feet above mean high water. The superstructure did not require renewal. This bridge was not used after the hurricane until October 4, 1938. The estimated cost of all work of renewal is \$170,000. One abutment of the railroad bridge at Quamby Cove was badly damaged and the other slightly. It was jacked back into place on temporary pile bents. In Groton, Connecticut, the track and fill at the south railroad bridge over Poquonock River was washed out. On the south side of the north embankment 6 to 8 feet of fill was washed away.

In New London, Connecticut, the drawbridge over the entrance to Shaws Cove was inundated and the electrical operating mechanism damaged. The station was flooded. Tracks were covered with wreckage. The U. S. Lighthouse Tender TULIP was washed ashore, blocking the east bound track of the main line of the New York, New Haven and Hartford Railroad, as shown on Plate 19. The railroad bridge at Norwich, Connecticut, was heaped with wreckage, and the freight shed was demolished. At Niantic the embankment was undermined and partially washed away. See Plate 12. The New Haven yard was damaged.

On the New London-Norwich, Connecticut, section of the Central Vermont Railway, ties and track floated off pile trestle bridges over tributaries of the Thames River. In New London a pier shed and platform and the station were damaged, and a freight house was destroyed. A considerable length of embankment was eroded between New London and Norwich. Replacement of fill, reballasting, track laying and resurfacing was a

major item of damage. Damage in this section, from wind alone, was as follows:

Buildings	\$11,830
Wires and Poles	3,200
Crossing Gates, etc.	<u>575</u>
	\$15,605

Emergency service by bus connection between Westerly, Rhode Island, and Saybrook, Connecticut, was restored on September 24th. On September 26th the section between Saybrook and New London, Connecticut, was put in service. Through freight service from New York to Providence was resumed on October 4, 1938, and through passenger service on October 5, 1938. The Central Vermont Railway from New London to Norwich, Connecticut, was reopened on October 4, 1938. The following estimates of damage by the hurricane wave were furnished by the New York, New Haven and Hartford Railroad and the Central Vermont Railway.

ESTIMATED TIDAL WAVE DAMAGE - SEPTEMBER 21, 1938.

New York, New Haven and Hartford Railroad
(Including subsidiary and leased lines)

Chatham, Massachusetts, to Greenwich, Connecticut.

Buzzards Bay to Hyannis, Massachusetts	\$ 100
Buzzards Bay to Woods Hole, Massachusetts	56,000
Middleboro to Buzzards Bay, Massachusetts	65,500
Tremont (West Wareham) to Fairhaven, Massachusetts	28,000
New Bedford to Watuppa (Fall River), Massachusetts	5,000
Mansfield to New Bedford, Massachusetts	43,200
Myricks, Massachusetts, to Newport, Rhode Island	123,150
Providence and East Providence, Rhode Island	71,000

Vanity Fair (East Providence) to Bristol, Rhode Island	\$ 200,000
Providence to Westerly, Rhode Island	40,800
Westerly, Rhode Island, to New London, Connecticut	636,359
Groton to Norwich, Connecticut	43,600
New London to New Haven, Connecticut	183,200
New Haven Yard, Connecticut	<u>16,000</u>
	\$1,511,909

Central Vermont Railway

New London to Norwich, Connecticut

Trackwork	\$ 58,295
Bridges and Culverts	5,140
Docks and Piers	16,345
Buildings	200
Plant	<u>2,700</u>
	\$ 82,680

Total Estimated Tidal Wave Damage

New York, New Haven, and Hartford Railroad	\$1,511,909
Central Vermont Railway	<u>82,680</u>
TOTAL	\$1,594,589

65. Summary. Railroad embankments exposed to wave attack were washed away or severely eroded, especially those encroaching on estuaries. Railroad bridges were generally of more substantial construction than highway bridges except on branch lines. Steel bridges suffered little damage except where their substructures were destroyed. Pile trestles presented too much surface to the attack and were carried away or heaved and twisted. It appears that loss restriction of estuaries by bridges and embankments

would be desirable. The anchoring of ties to bridges to prevent the track structure from floating away might be considered.

66. Damage to Harbor Structures.

a. Breakwaters and Jetties. - Practically all of these structures in this District are of the rubble mound type. Where exposed to violent wave attack they were washed down. Cap and side stones weighing many tons were thrown off into the water, but few if any structures were so badly damaged that they did not serve their purpose. The Point Judith breakwater is of heavy construction. The main breakwater and east shorearm have a top width of 20 feet at an elevation of 10 feet above mean low water, with side and capstones weighing from 3 to 10 tons or more. A large amount of stone was displaced. Several breaches were nearly to low water. It is located at one of the most exposed locations in the District, and part of it was directly across the direction of the wind and wave approach. Structures at the following locations, built or maintained by Federal funds, have been examined since the hurricane to determine whether maintenance is required at the present time. All are of riprap construction. Estimated tonnages of stone and estimated costs of repairs are included in the following tabulation. Most of these structures were in fair to good condition prior to the hurricane. Actual hurricane damages are, therefore, little less than the estimated amounts.

(Tabulation given on following page.)

ESTIMATED COST OF BREAKWATER AND JETTY REPAIRS

<u>Location</u>	<u>Estimated Tonnage Long Tons</u>	<u>Estimated Cost</u>
Cuttyhunk, Massachusetts	450	\$ 3,600
Sakonnet, Rhode Island	1,000	5,000
Block Island Harbor of Refuge, Rhode Island	3,700	22,500
Point Judith Harbor of Refuge, Rhode Island	54,000	324,000
Stonington, Connecticut	9,400	44,000
Duck Island Harbor of Refuge, Connecticut	4,900	23,500
Saybrook Jetties, Connecticut	2,100	10,500
New Haven, Connecticut	6,200	25,000
Milford, Connecticut	225	2,000
Housatonic River Jetty, Connecticut	1,600	9,000
Bridgeport, Connecticut - Main Harbor	4,000	16,000
Bridgeport, Connecticut - Black Rock Harbor	1,000	<u>10,000</u>
		\$ 495,100

Available general information on other breakwaters and jetties follows:

The State jetties at Menemsha Pond on Marthas Vineyard were damaged to the extent of about \$10,000. It was reported that the breakwater in Appona-gansett Bay appeared battered and that a breakwater at the north end of Potomska Neck was demolished. Stone from the State jetty at the mouth of the Westport River was scattered. Cost of repairs is estimated at about \$5,000. A breakwater extending northward from the north end of Goat Island in Newport Harbor was damaged. Of its present length of 520 feet, about 250 feet were practically destroyed to low water, the stones being thrown eastward into the harbor. The estimated cost of rebuilding

this breakwater to its former condition is \$11,000. The entrance to Point Judith Pond, a State project, was protected on its east side by a stone jetty joining a steel sheet piling bulkhead. The inner end of this jetty and the outer end of the bulkhead were breached, as shown on Plate 16, estimated damage being \$17,000, about half of which was to each structure.

At Watch Hill, Rhode Island, two timber groins survived, which had been completed about a week before the storm. These groins, shown on Plate 24, were not supported by piles, but consisted only of 3-inch wooden sheeting with 8-foot penetration and 2-1/2 or 3 feet projecting above the beach. A cap of two 6" x 6" timbers held the sheeting together. The groins extended from mean high water line to mean low water line, a length of 60 feet. The inner ends abutted against a seawall or bulkhead, which was destroyed, leaving the ends projecting about 4 feet above the beach surface.

b. Seawalls and Bulkheads. - A great variety of seawalls and bulkheads existed throughout the District. Most were constructed by private interests. Many were adequately designed for protection from ordinary storms, but could not cope with the hurricane wave attack. Their destruction in the region from Buzzards Bay to Saybrook was almost complete. Most of the seawalls destroyed were of plain concrete or rubble masonry. Apparently little consideration had been given to the elevation of the bottom of the wall, or the character of the foundation material. The rubble masonry walls were poorly bonded, frequently having little or no mortar except the pointing of the face. Many had received no maintenance since their construction. In many cases the stability of the walls depended upon the resistance of the backfill behind them. Few had counterforts

to help prevent washing. As soon as the backfill was washed out the walls toppled over.

The wall at Newport Beach, shown on Plate 13, presents an instance of a rubble masonry wall of small stones poorly bonded. This wall varied in height and cross section but was sufficiently massive to withstand great forces if it had been of monolithic construction. However, the vibration caused by waves breaking against its face soon loosened the little mortar present, and the small stones were quickly scattered. Only a few short sections of this massive wall remained after the hurricane. Walls at Narragansett Pier were partly concrete and partly masonry. These walls were founded deeply enough in a boulder beach so that no foundation failure was encountered. The monolithic concrete wall, shown on Plate 15, withstood the attack while the rubble masonry wall was destroyed.

Two adjacent seawalls just north of Point Judith afforded a good comparison of differences in design and construction. The south wall is 4 feet thick and was 8 feet high. It is composed of low grade concrete, poured around and between many smooth round boulders. The bottom of this wall is about 1 foot above mean low water. The north wall, shown on Plate 14, is of good grade reinforced concrete and had a sloping sea face. It is 12 feet high and 5 feet thick at the base at about mean low water. The rear face is vertical and the front sloping. The upper 4 feet have a uniform thickness of 1 foot. The south wall was slightly more nearly normal to the hurricane wave attack. The heavy section of both walls provided stability against overturning, and the resistant character of the shingle beach may be regarded as the reason for safety against undermining. The top section of the south wall was swept away. It appears

that this section was a separate pour and that no attention had been given to securing a bond at this construction joint. The north wall was practically unharmed, although a large volume of backfill was washed away, as shown on Plate 14. The battered lower section provided stability as a gravity section and prevented overturning after the backfill disappeared. The reinforcing of the thin upper section can be credited for lack of damage to this portion.

Failure due to lack of proper foundation is illustrated by the wall, shown on Plate 15, at the Point Judith Coast Guard Station. This wall was a reinforced concrete wall of good construction, built in sections about 10 feet in length with V-shaped construction joints between sections. No sign of breaking up was observed. This may be attributed to the reinforcing and the quality of the concrete. When the bank in front of this wall and the backfill in the rear were washed away, many sections of the wall were easily overturned, some landward and others seaward. The overturned blocks revealed the lack of footings. The base of the wall was well above low water elevation. The wall was practically of uniform thickness from top to bottom. An attempt had been made to anchor each section by a substantial bar to heavy concrete blocks imbedded in the bank about 10 feet to the rear of the wall. When the upper bank was eroded these anchors were of no value. If this wall had a spread footing to provide stability as a gravity section, or had been carried down below the limits of erosion, it would probably have resisted the attack.

A bulkhead of steel sheet piling along the east side of the Point Judith Pond entrance channel was bent westward toward the channel at its outer end where it joined the stone jetty. See Plate 16. As shown on

the permit plans, this sheet piling had a penetration of 7.5 feet below the side slope of the channel, at the bulkhead, but only 1.5 feet below the bottom of the dredged channel at a distance of only 12 feet from the bulkhead. Oak piles spaced about 9.8 feet on centers had slightly greater penetration. The bulkhead was anchored by 1-1/2 inch diameter rods spaced at 9.8 feet to a continuous wooden deadman consisting of three 12" x 12" pieces of fir. No sign of the anchors was visible at the date of inspection. This entrance channel was reported to have scoured about 6 feet in places. It seems probable that failure was due to loss of supporting material on the channel side. A steel sheet piling bulkhead at Silver Beach, Milford, withstood the storm although the beach in front of it appeared to be washed down several feet.

c. Docks and Piers. - Many docks and piers were destroyed or damaged throughout the District. Many of those destroyed were old and depreciated. Generally only piling or supports were left in place. See Plate 17. Frequently sheds and other buildings were washed off carrying the flooring with them. Flooring not properly anchored to withstand such high water was torn loose and floated off. Structures of recent construction well bolted and tied together to act as a unit generally withstood the attack. Much damage to docks and piers was caused when they were struck by drifting boats and other wreckage.

d. Lighthouse Structures. - These structures were generally well designed and built to withstand exposure to heavy storms. Those in exposed locations suffered severe damage. See Plate 18. Whale Rock Light, at the entrance to the West Passage of Narragansett Bay, was demolished. The Superintendents of Lighthouses report damage to light

structures and supply depots as follows:

Chatham, Massachusetts, to Point Judith, Rhode Island	\$475,000
Block Island, Rhode Island, to Greenwich, Connecticut	<u>314,250</u>
Total in Providence District	\$789,250

In addition, damage of \$42,250 was reported to the Tender TULIP which was washed ashore at New London, Connecticut, as shown on Plate 19.

67. Summary. - Rubble mound breakwaters and jetties suffered displacement of stone, but were not destroyed. In general, sections of breakwaters proved satisfactory for the exposure for which they were designed. No serious failure occurred. Heavier construction to withstand hurricane wave attack would be of doubtful economy. It is probable that the annual charges on the excess cost of an expensive design would exceed cost of repairs.

Many walls which were washed out could not be said to have failed to perform their functions. They were not designed to resist hurricanes. They had for many years resisted the storms, great and small, which were less than hurricane force. Nor should they be so designed when hurricane frequency is from 60 to 75 years. To completely and adequately resist hurricane forces would require walls comparable to those used in regions where hurricanes are of almost annual occurrence and hence where their expense is warranted, as at Galveston and in Florida. Such walls cost from \$100 to \$200 per lineal foot. A wall should be designed to resist the forces of the great, but not necessarily the maximum possible storms of its location with a good factor of safety. It would be more economical to suffer the entire loss of a number of such walls in a half or three-fourths of a century period than to build a super-wall to meet the emer-

gency occurring once in such a period.

Many seawalls and bulkheads that were satisfactory protection against ordinary storms proved inadequate to withstand hurricane wave forces. Those which withstood the attack indicate that proper design and construction would provide walls able to cope with these forces at little greater cost than that of the old structures. The following features should be carefully considered in the design and construction of future walls and bulkheads.

1. Foundations should be carried to or below mean low water elevation. Where this is impractical, the beach in front of the structure should be protected from erosion by some method such as paving or groins. Pile foundations may be necessary where the beach material is very erodible. Bulkhead piling should be carried well below channel bottoms, or the channel bottom or slope should be protected against scouring adjacent to the structure.

2. Counterforts, or cutoffs, should be provided to prevent washing out of backfill. Paving of the backfill might be desirable in some locations.

3. The section should be designed for stability as a gravity section without dependence upon the pressure of the backfill.

4. Walls with battered face and with an outward curved top give greater resistance than vertical face walls.

5. Good materials and workmanship are necessary. Rubble masonry walls would have greater strength if built with larger stone, well bedded in cement mortar for the full thickness of the wall, to insure monolithic action. Maintenance of masonry walls is of prime im-

portance. Concrete walls should be of dense, well spaded concrete of good quality.

Modern construction of docks and piers appeared to be satisfactory. Attention to firmly securing all parts to bind the structure into a solid unit is important.

68. Damage to Army and Navy Posts. - Posts located close to the shore line sustained considerable damage. At Fort Rodman it was reported that about ten houses were swept from their foundations and destroyed. The seawall around the reservation was demolished. One large pier was badly damaged, having the concrete roadway and railway tracks washed off it. At Fort Adams the following damage was reported:

Buildings carried away or destroyed	\$ 9,960
Roads, riprap, etc., washed out	8,512
Trees damaged	200
Sewer and electric lines	800
C. M. T. C. damage	544
Buildings and structures damaged	4,840
Miscellaneous material and equipment	2,144
Hand tools and equipment	5,743
	<hr/>
	\$32,743

The following damages to Forts H. G. Wright, Michie and Torrey, and to the Government dock and harbor boats at New London, Connecticut, have been reported.

Damage to Fort H. G. Wright, New York.

Practically every building on the reservation was damaged to some extent, the principle damage being to roofs, porches, chimneys and windows. Estimated cost of restoring structures and utilities is \$208,128. In addition to the above, there were 20 buildings and structures either totally destroyed or damaged beyond economical repair, the replacement of which it is estimated will cost \$64,750.

The National Guard Camp, located on the southwest side of the reservation on the shore, was practically demolished. Estimated cost of replacement \$86,207.

Damage to Fort Michie, New York.

Five buildings on the post were damaged to the extent of \$29,136. The dock was damaged to an estimated extent of \$4,000.

Damage to Fort Terry, New York.

Twelve buildings and structures on this post were damaged to the estimated extent of \$45,746. In addition, two buildings were demolished and would require \$3,000 to rebuild.

Damage to Government Dock, New London, Connecticut.

Estimated damage to the dock, including the dock house, \$4,500.

In addition to the damage noted above to the dock, the harbor boat JESUP was damaged to an estimated extent of \$20,000. This was caused by the Fishers Island ferry boat being blown up the river by the force of the hurricane into the JESUP, which was moored at the dock, breaking her ribs, disabling her rudder and causing the damage to the dock noted above.

The harbor boat GREENE, which was moored at the other side of the dock, was damaged to estimated extent of \$3,500. This damage was incurred when the freighter CENTRAL VERMONT broke away from her dock across the cove and was blown into the GREENE forcing the GREENE up the cove and aground.

Damage to engineer installations was estimated at \$40,000 for the three posts.

Damage to Naval Torpedo Station, Newport, Rhode Island.

The Naval Torpedo Station at Newport, Rhode Island, reports the following damages: Motors and machinery submerged, floors warped, buildings undermined, small buildings demolished, gradings washed out, sea walls broken or washed out, roofs torn, loose or off, windows broken, equipment washed away, piers washed out, trees uprooted. Estimated damage - \$328,000.

Damage to Coast Guard Stations.

Plate 18 shows damage to Brenton Point Coast Guard Station. The cost of rebuilding and reequipping Coast Guard Stations in Rhode Island was estimated as follows:

Brenton Point	\$ 65,950
Narragansett	3,000
Point Judith	66,650
Watch Hill	76,100
Block Island	<u>5,500</u>
	\$217,200

Damage to Submarine Base, New London, Connecticut.

The Submarine Base at New London, Connecticut, reported total damage of \$132,550. Most was water damage to buildings. Damage to piers, small boats and lighters was minor.

Damage to Coast Guard Academy, New London, Connecticut.

The Coast Guard Academy reported the following damages and estimated loss:

Two-masted Schooner DOBBIN, sunk at pier	\$100,000
Two-masted Schooner CHASE, damaged at pier	5,000
Small boats destroyed	7,400
Small boats damaged	2,284
Miscellaneous equipment	1,369
Shore buildings damaged	6,850
Clearing debris after the storm	<u>3,000</u>
	\$125,903

The estimated damages to Army and Navy Posts and Coast Guard Stations total about \$1,250,000. Reported damage to floating equipment totals about \$140,000.

69. Damage to Commercial Property. - Waterfront commercial and industrial property was damaged by flooding in most of the ports of this District. The heaviest loss occurred in Providence, Rhode Island, where a 1-1/4 square mile area of the business district, extending for a considerable distance from the waterfront, was flooded. Figure 29 shows the developed portion of the inundated area. Telephone, electric and gas properties are located in the flooded area. Generating equipment in the power plant on the waterfront was damaged by salt water. After removal of the salt, the equipment was dried in two temporary ovens laid up of fire brick and heated by steam in the turbine room. Units were restored to service one by one. Energy for trolley service was restored by the evening of September 24th. Up to that time emergency transportation service had been rendered by gasoline busses. Full capacity service of the waterfront power station was restored on October 2nd. Another steam plant was restored to full operation the following day. Meanwhile, flooded underground distribution had been pumped dry, cleaned and replaced. About 200 miles of underground cable were in the area flooded. This network was ready to be energized on September 30th. Even then service could not be completely restored. The restoration of current to damaged customers' services before overhaul and inspection would have been a serious fire hazard. It was many weeks before lights and elevator service were available in some downtown buildings.

Similar damage to telephone underground plant and equipment occurred.

Restoration of telephone service to many offices took weeks.

The Providence Gas Company, serving Providence and adjacent towns, reported total loss of \$315,000, a large proportion of which was suffered in Providence and East Providence. The main plant was inundated to a depth of 5 to 6 feet above the yard level. Without steam, power or lights it was impossible to make gas for about 24 hours. During this time the reserve gas in the holders kept up the supply. Then with the use of hand power and many emergency arrangements a limited output was made on water gas machines. Coke ovens were not started until October 3rd. Part of the difficulty was due to fire in the boiler house, caused when oil floated in on the water. Water and fire loss at the plant totalled about \$181,000. Wind damages to coal unloading bridges amounted to \$17,500. Cost of pumping water out and repairing underground service and meters totalled \$22,000. The office building in downtown Providence had 5 feet 8 inches of water on the showroom floor. Damages to the building were \$12,500, and to appliance stock \$12,000. In East Providence a gas holder built in 1873 was damaged by the wind. Escaping gas became ignited, completing the holder's destruction. Its value was figured at \$45,000. Loss of revenue to the company was computed to be \$25,000. Wind loss totals about \$65,000 and water loss about \$250,000.

Most of the larger business establishments in Providence, including banks, office buildings, hotels, stores, restaurants, and warehouses, are in the inundated section. Many stores were not reopened for several weeks. Two photographs included as Plate 22 show the flood near its peak. The City was totally unprepared for a flood. Automobiles, trucks, busses and trolleys were hastily abandoned as the water filled the streets, as

illustrated on Plate 22. No opportunity was afforded to shift stock beyond reach of the water. The salt water also made the losses greater than a similar fresh water flood would have caused. Damage to buildings and equipment, loss of stock and revenue were large.

Table 4 following gives assessed property valuations, estimated direct and indirect losses for Providence as determined by this office. Direct losses are the physical damage to property and goods, measured by the present day cost of repair, or replacement in kind, and cost of clean-up and moving goods. Direct losses were estimated by personal contact with officials of typical firms and those sustaining major losses. The direct losses of those contacted amount to \$4,658,000, or 45% of the total direct damage. Other losses were estimated by systematic inspection of the properties flooded, and an allowance for damage to buildings of 2 to 10% of their assessed valuations.

Indirect losses are the value of service or use, either lost or made necessary by reason of flood conditions. They include losses of business and wages and similar losses, both within and without the flood area, sustained during the period of flood and subsequent rehabilitation. They were estimated as a percentage of the direct loss for different types of property affected. Percentages used ranged between 50% for commercial areas and 100% for industrial areas, in accordance with indirect flood loss studies in cities along the Connecticut River.

ESTIMATED HURRICANE FLOOD LOSSES IN PROVIDENCE, RHODE ISLAND.

Damage Zones	Assessed	Losses		
	Valuations	Direct	Indirect	Total
1 - Business area limited by: Pine, Main, the railroad: and Fountain Sts., and southwesterly limits of flood area.	\$ 67,514,070:	\$ 5,396,600:	\$ 2,698,300:	\$ 8,094,900
2 - Northwest of Fountain St. to railroad.	4,006,620:	286,300:	143,200:	429,500
3 - Brown & Sharpe area. west to Pleasant Valley Parkway.	2,961,096:	143,100:	100,200:	243,300
4 - Harris Ave., warehouse area, east of Pleasant Valley Parkway.	4,652,500:	121,400:	121,400:	294,900
5 - West of Pleasant Valley Parkway, north bank of Woonasquatucket River.	2,924,260:	306,700:	306,700:	613,400
6 - West of Pleasant Valley Parkway, south bank of Woonasquatucket River.	3,420,230:	271,500:	217,200:	488,700
7 - Canal Street warehouse area south to railroad.	2,772,194:	232,600:	116,300:	348,900
8 - Main St., south of head of navigation limited by: Benefit St. on east.	1,770,107:	410,700:	205,400:	616,100
9 - West side Providence River, Pine to Point St.	20,483,660:	1,627,700:	1,139,400:	2,767,100
10 - West side Providence River, Point St. to City Line.	15,090,702:	1,432,300:	1,002,600:	2,434,900
TOTALS	\$125,595,439:	\$10,281,000:	\$6,050,700:	\$16,331,700

Similar but less extensive damages were sustained in most of the commercial centers, from the head of Buzzards Bay to New Haven, Connecticut. Losses as reported by towns and cities are included in Table 5. Some items have been revised in view of more complete or recent information. For towns from which no damage statement was received, an estimate is included for commercial and residential losses based on exposed frontage, nature and extent of development. At New London, Connecticut, a disastrous fire followed the flood. Whether the wind or the water were the cause of its origin is not definitely known. The wind undoubtedly caused it to spread. The difficulties of fighting the fire were greatly increased and the resulting damage was much greater because of the hurricane. The flood damage estimate for New London without fire loss is placed at about \$3,000,000, with probably a similar sum due to wind and fire.

Bath houses at almost all beaches in the district were destroyed. Plate 24 shows where the beach club, bath houses and dwellings were completely swept from Napatree Beach at Watch Hill, Rhode Island. Most beach buildings were of frame construction and were located within reach of the hurricane wave. An exception was the stone bath house at Scarborough Beach, Rhode Island, which although flooded was damaged little. Many resort hotels built on low land were wrecked. Most were of frame construction. Plate 23 shows typical destruction. Buildings of substantial construction were also damaged at some locations. Plate 17 shows the smashed stone wall of the armory at Bristol, Rhode Island.

Many automobiles were flooded and some completely destroyed. Some were caught by the hurricane wave as they were driven along shore roads, and are still visible in the ponds behind barrier beaches. The greatest loss to

automobiles occurred in Providence, Rhode Island, where those flooded in the streets, on parking lots and in garages in the business district number about 2,000, with damage amounting to about \$500,000. This damage is included in the figures in Table 4.

Inland considerable damage was done to mill buildings by wind alone. Many of these were brick buildings. The damage generally consisted of unroofing and destruction of the brick walls of the upper story when inadequate roof anchors were pulled out of the brickwork by the wind uplift on the roof. The small additional cost of making these structures practically immune from serious wind damage by greater attention to proper roof anchorage is clearly justified.

70. Damage to Private Residential Property. - Loss of residential property was very extensive. Beaches that were closely built up for miles were left with hardly a trace of the former dwellings. Most were for summer occupancy, but those for all year use reached a considerable figure. Practically all were of frame construction. Buildings situated out of reach of the hurricane wave were damaged little, except in minor details such as chimneys, windows and doors. Few frame structures were unroofed. The structures that were demolished by wind alone were generally weakened by age and lack of maintenance. It was evident that little change in method of construction would be needed to withstand wind forces of 100 to 125 miles per hour.

Residential structures that were reached by the hurricane tide and wave attack offered little resistance. Plates 24, 25 and 26 show typical destruction of structures on low wave-built land forms. Barrier beaches that were swept clear of buildings include East Horse Neck Beach, Westport, Massachusetts, Charlestown Beach, Rhode Island and Napatree Beach, Westerly.

Rhode Island. The latter is shown on Plate 24. In some cases buildings were floated from their foundations. They drifted across ponds to the mainland under the pressure of wind and current, and some were found in fair condition. Structures which did not float off were battered by wave action. Instances occurred where the first story was smashed to pieces, freeing the second story to float away. Structures located on high sand dunes were damaged by wind only, except that in some locations erosion of the dune front removed the support as shown on Plate 5. Some of the buildings thus undermined toppled forward onto the beach. Estimated losses of private residential property by towns are included in Table 5.

The Red Cross reports as follows:

Number of permanent homes destroyed	1,991
Number of summer homes destroyed	6,933
Number of permanent homes damaged	7,438
Number of summer homes damaged	42,743

Improved foundations and methods of anchoring structures exposed to hurricane wave attack would be of doubtful value. Those not floated away would remain to be demolished by the waves. Sufficient structural strength might be provided in future construction, as is evidenced by the stone bath house at Scarborough, Rhode Island, but the use of this rugged construction for all exposed structures would be impractical. The only way to prevent future destruction such as that shown on Plates 24, 25 and 26 is to discontinue the use of land lower than 20 feet above mean high water for residential purposes.

ESTIMATED DIRECT PROPERTY DAMAGES BY HURRICANE WAVESEPTEMBER 21, 1938MASSACHUSETTS

<u>Town or City</u>	<u>Harbor Structures</u>	<u>Commercial</u>	<u>Residential</u>	<u>Total</u>
Nantucket			\$ 2,500	\$ 2,500
Edgartown		\$ 70,000	300,000	370,000
Tisbury			10,000	10,000
West Tisbury			2,000	2,000
Chilmark	\$ 10,000	25,000	40,000	75,000
Gay Head			10,000	10,000
Gosnold		5,000	20,000	25,000
Yarmouth			6,000	6,000
Falmouth		50,000	450,000	500,000
Bourne			200,000	200,000
Wareham			200,000	200,000
Marion			200,000	200,000
Mattapoissett	32,000	7,300	1,235,000	1,274,300
Fairhaven		10,000	40,000	50,000
New Bedford	68,227	2,763,532	43,095	2,874,854
Dartmouth		2,000	240,000	242,000
Westport	5,000	50,000	1,200,000	1,255,000
Fall River	200,000	800,000		1,000,000
Freetown		5,000		5,000
Berkley		1,000		1,000
Dighton		5,000	5,000	10,000
Somerset	15,000	53,000	95,000	163,000
Swansea			25,000	25,000
Sub-totals				
Massachusetts	\$330,227	\$3,846,832	\$4,323,595	\$8,500,654

TABLE 5 (Continued)

RHODE ISLAND

<u>Town or City</u>	<u>Harbor Structures</u>	<u>Commercial</u>	<u>Residential</u>	<u>Total</u>
Little Compton		\$ 50,000	\$ 200,000	\$ 250,000
Tiverton		100,000	200,000	300,000
Portsmouth		50,000	200,000	250,000
Middletown	\$ 15,000	24,800	126,420	166,220
Newport	310,000	400,000	40,000	750,000
Jamestown	50,000	50,000	300,000	400,000
New Shoreham (Block Island)	2,000	82,000		84,000
Bristol	50,000	300,000	150,000	500,000
Warren		175,000	50,000	225,000
Barrington	164,936		469,716	634,652
East Providence		350,000	250,000	600,000
Pawtucket		171,000		171,000
Providence		10,281,000		10,281,000
Cranston	16,000	51,000	80,000	147,000
Warwick		250,000	750,000	1,000,000
East Greenwich		10,000		10,000
North Kingstown	15,000	27,000	200,000	242,000
South Kingstown	21,600	49,500	642,050	713,150
Narragansett	117,000	300,000	100,000	517,000
Charlestown		150,000	850,000	1,000,000
Westerly		400,000	1,000,000	1,400,000
Sub-totals Rhode Island	\$761,536	\$13,271,300	\$5,608,186	\$19,641,022

TABLE 5 (Continued)

CONNECTICUT

<u>Town or City</u>	<u>Harbor Structures</u>	<u>Commercial</u>	<u>Residential</u>	<u>Total</u>
Stonington	\$ 50,000	\$ 100,000	\$ 150,000	\$ 300,000
Groton	17,500	250,000	700,000	967,500
New London	500,000	2,500,000		3,000,000
Waterford			100,000	100,000
East Lyme			200,000	200,000
Old Lyme			250,000	250,000
Old Saybrook			250,000	250,000
Westbrook	130,000		225,000	355,000
Clinton	50,000		267,337	317,337
Madison	100,000		150,000	250,000
Guilford			700,000	700,000
Branford			500,000	500,000
East Haven			300,000	300,000
New Haven	60,000	90,000		150,000
West Haven	50,000	150,000		200,000
Milford		2,000	60,000	62,000
Stratford	2,000		10,000	12,000
Bridgeport	37,900	48,450		86,350
Fairfield			50,000	50,000
Westport	82,000	10,000		92,000
Norwalk		10,000		10,000
Stamford		50,000		50,000
Greenwich		30,000		30,000
Sub-totals Connecticut	\$1,079,400	\$3,240,450	\$3,912,337	\$8,232,187
TOTAL	2,171,163	20,358,582	13,844,118	36,373,863

72. Recapitulation of Damages

Estimated direct flood damages described in the foregoing sections may be summarized as follows:

Inlets and Channels	\$ 50,000
Oyster Beds	145,000
Cost of Wreck Removal	53,000
Shipping	550,000
Pleasure Craft	600,000
Government Vessels	206,230
Bridges and Highways	1,000,000
Railroads	1,594,589
Federal Breakwaters and Jetties	506,100
Lighthouse Service	789,250
Army, Navy and Coast Guard Stations	1,250,000
Private and Local Government Property:	
Harbor Structures	2,171,163
Commercial and Industrial	20,358,582
Residential	<u>13,884,118</u>
Total	\$43,190,032

Of the foregoing losses the following were sustained by the Federal Government. In addition, an unknown sum was spent through the W.P.A. for cleaning up.

Federal Government Loss

Breakwaters and Jetties	\$ 506,100
Lighthouse Service	789,250
Army, Navy and Coast Guard Stations	1,250,000
Cost of Wreck Removal	50,000
Government Vessels	206,230
Post Office-Providence, Rhode Island	28,500
Custom House-Providence, Rhode Island	<u>1,000</u>
Total	\$2,831,080

In arriving at the \$43,000,000 total of direct losses, efforts were made to avoid the inclusion of losses that were a direct effect of wind, without flood or wave action. Losses by direct wind effect were large. One group of insurance companies reports wind loss totalling \$3,920,000 on more than 900 industrial plants. The severest damage occurred in

Massachusetts, Rhode Island and eastern Connecticut. At 84 plants, the estimated damage was over \$10,000, and at nine, the damage exceeded \$100,000, the largest loss being estimated at a quarter million dollars. The loss to the telephone companies in New England, New York and New Jersey was estimated at \$10,000,000, a large percentage of which was caused by wind alone. Altogether, approximately half a million telephones were out of service. Much of the damage was caused by trees falling across and severing telephone lines. It was reported that in New Hampshire, trees equivalent to thirty years' total normal timber harvest were blown down.

The indirect loss in the City of Providence, computed as indicated in a preceding section, totalled about \$6,000,000, or at an average rate of about 60 per cent of the direct commercial and industrial losses. On the same basis indirect losses for Massachusetts, Rhode Island and Connecticut would total \$12,000,000. Total hurricane flood losses are therefore as follows for this District:

Direct Hurricane Flood Loss	\$43,000,000.
Indirect Hurricane Flood Loss	<u>12,000,000.</u>
Total Hurricane Flood Loss	\$55,000,000.

Damage estimates submitted in the preliminary report, when no attempt was made to exclude direct wind losses, totalled about \$69,000,000. When submitted, that figure was considered low. It is evident that the addition of direct wind damages to the \$55,000,000 total of flood losses would bring the total above the preliminary figure.

CONCLUSIONS

73. Economic Feasibility of Protection. On the exposed outer shore, seawall protection from high water and wave attack would be very expensive. On barrier beaches the property to be protected frequently consists of a single row of dwellings. In some cases the cost of protection would be greater than the value of the property to be protected. Protection against storms of an average frequency of seventy-five years is clearly unwarranted.

In bays and rivers wave attack is much less severe. Walls of lighter construction would serve to hold back the flood waters. Most of the cities have grown on these harbors. In cities where flooded property extends along considerable length of waterfront, justification of protection appears unlikely. In Providence, Rhode Island, property valued at many millions of dollars is concentrated in a relatively small flooded area. A portion of Providence inundated by the 1938 flood is shown on Figure 29. The total assessed valuation in this area is about \$126,000,000. Direct and indirect flood losses in this area total about \$16,000,000 as shown in Table 4. All sections except 8 and 10 could be protected by a flood wall about 4,000 feet in length, with gates or other provision for the fresh water flow of the Woonasquatucket and Moshassuck Rivers. The total assessed valuation of this area is about \$109,000,000, and the estimated 1938 direct and indirect flood loss totals \$13,000,000. On the basis of a seventy-five-year frequency the average annual loss would be about \$175,000.00. The capital expenditure warranted for protection could only be ascertained by further detailed studies of benefit to cost relationships.

74. Recapitulation

The study of the 1938 and previous hurricanes in this region leads to the following conclusions:

- a. Tropical cyclonic storms of hurricane intensity have occurred in New England at an average interval of about seventy-five years since the earliest one of record in 1635. Others reach this area with intensity diminished, at an average of twenty years apart. Any of the disturbances born annually in the tropics requires only an unfortunate location of adjacent high pressure areas to bring it over New England. There is no reason for a feeling of complacency now that this generation has had a hurricane.
- b. The high winds of the hurricanes cause much damage inland, but the greatest destruction and loss of life is caused by the attendant hurricane tidal wave which rapidly inundates the low land of the coastal region.
- c. Each succeeding hurricane has exacted a greater toll as occupancy of the shore front has increased. If development of low wave-built land forms for residential purposes continues, it may be predicted that a future hurricane will cause greater loss of life and property. A hurricane occurring earlier in the season, while summer residences were still occupied, would have resulted in far greater loss of life.

- d. The destruction is effected by flooding of low elevation sites as well as by wave attack. The wave attack in exposed locations is violent up to the elevation attained by the crest of the wave.
- e. Shore erosion above mean high water line greater than that of many years of normal shore processes occurs in a few hours. In general, the high and low water lines showed little recession.
- f. Rubble mound breakwaters, jetties and groins generally proved satisfactory for their purpose. Many seawall failures indicated lack of good design and construction methods.
- g. The natural bulkhead of sand dunes proved to be a valuable defense against wave attack. As such, dunes should be protected and maintained. Artificial cuts through dunes, as for pathways, make them more vulnerable.
- h. Modern docks, piers and bridges withstood the attack well. The advisability of greater clearances for bridges was indicated. Damage to bridge operating machinery, particularly electric motors and auxiliary power installations, would in some cases have been avoided if placed at higher levels.
- i. The failure of heat, light and power sources caused almost a complete breakdown of communication, transportation and lighting facilities, some of which took weeks to restore.

- j. Ordinary modern building construction generally withstood the hurricane winds. Some unroofing occurred, indicating the need of attention to adequate roof anchorage. The cost of buildings that could stand the wave attack would be unwarranted.
- k. The cost of protecting buildings on low land from hurricane wave attack would in many cases be greater than the value of the structures. Wave-built land forms that have proved unsatisfactory for residential use should be converted to recreational areas with safe means of egress in time of storm.
- l. The possibility of protecting property of high valuation concentrated in a small area warrants further study.
- m. An improved warning service would reduce loss of life in future hurricanes.



J. S. Bragdon
Lieut. Col., Corps of Engineers
District Engineer

United States Engineer Office
Providence, Rhode Island
June 17, 1939

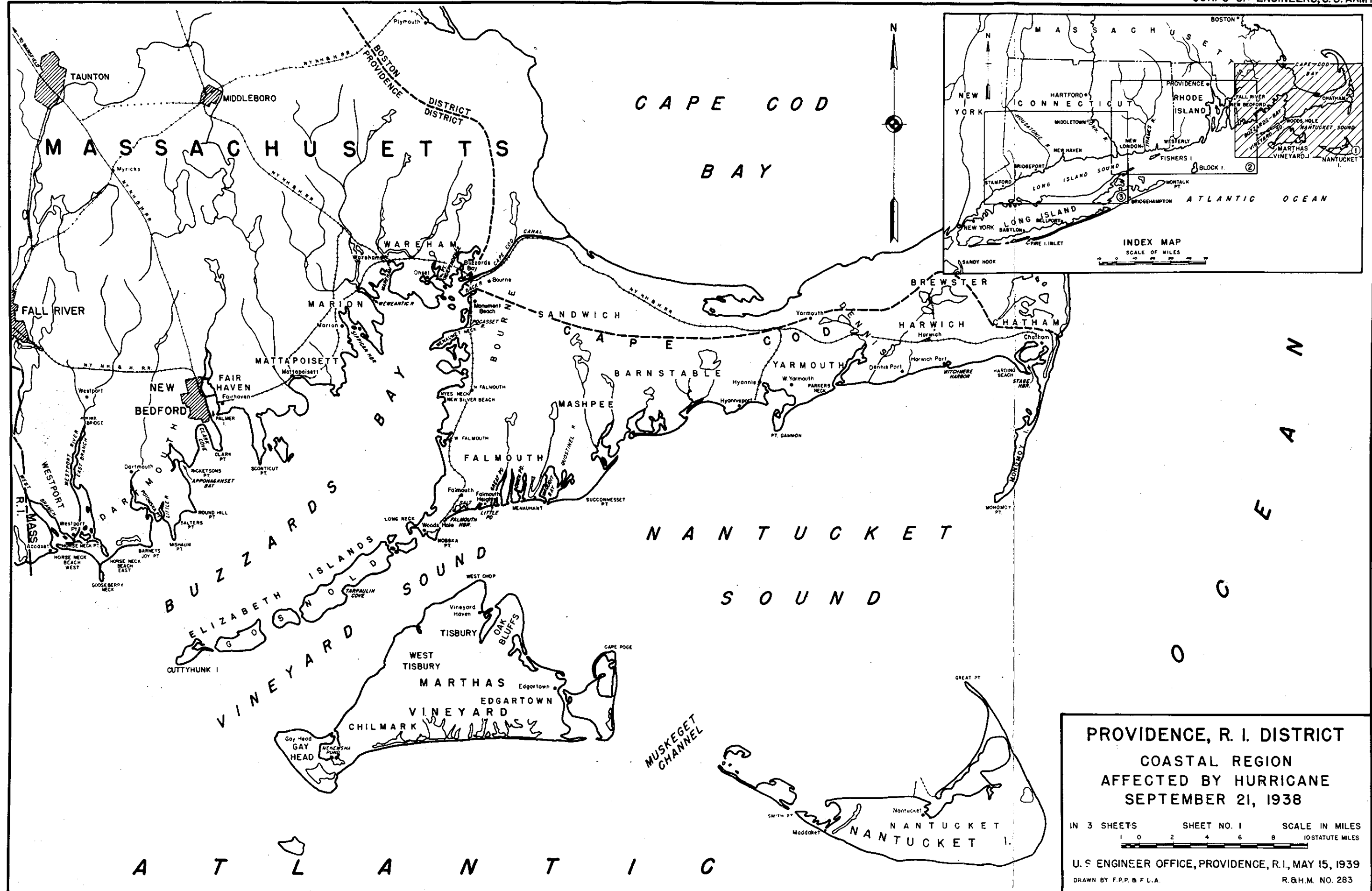


FIGURE 1

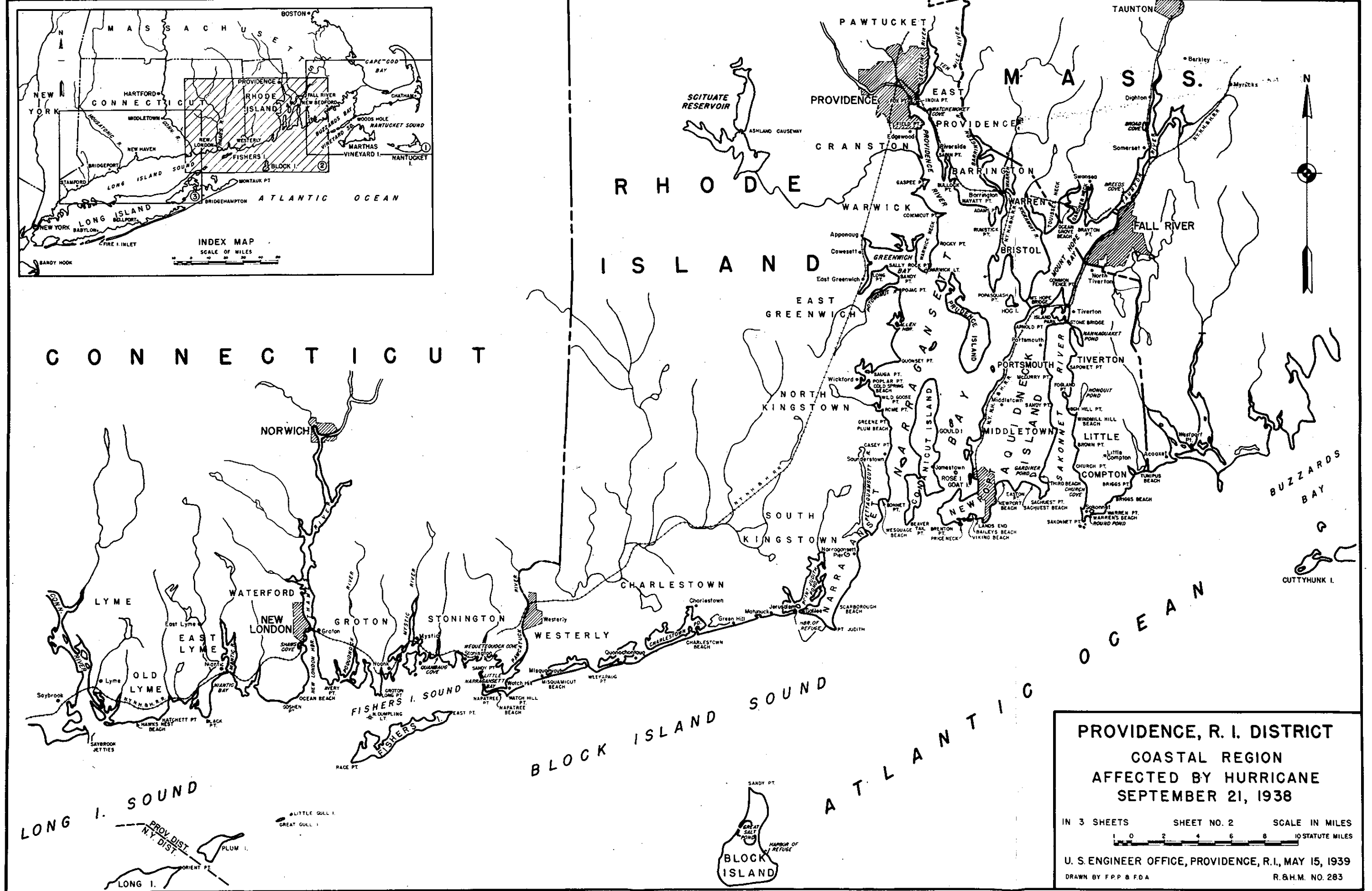


FIGURE 2

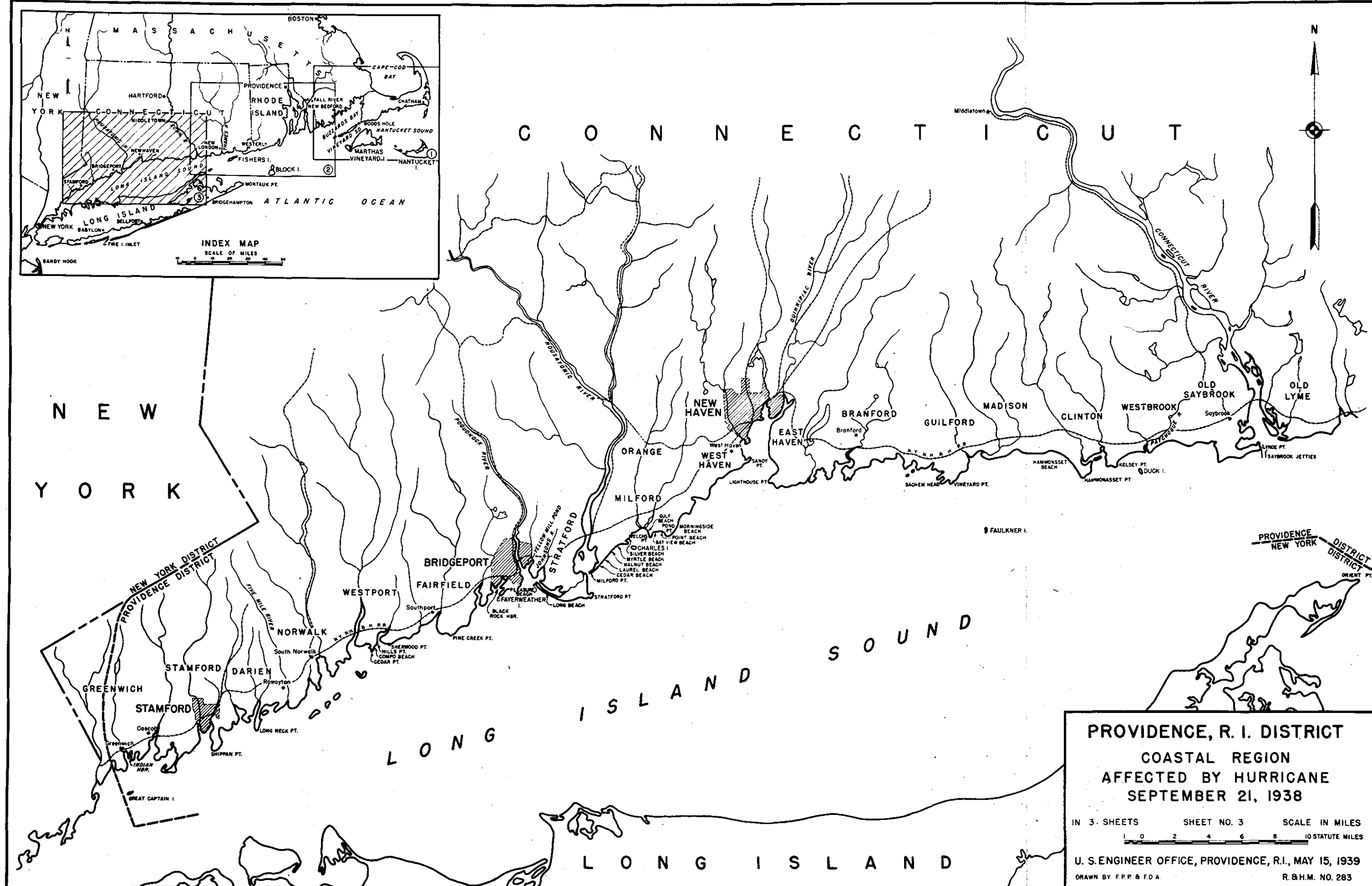
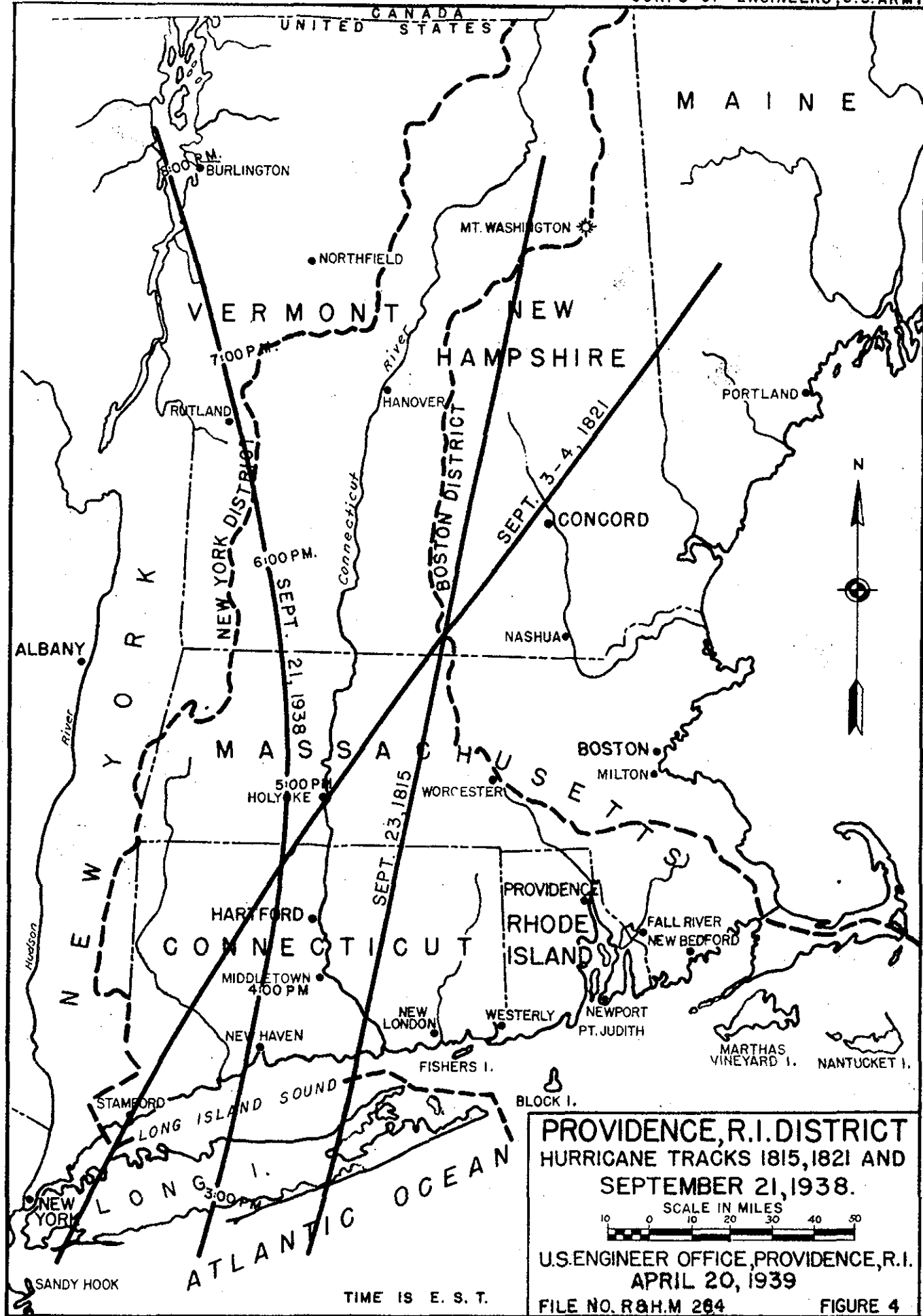
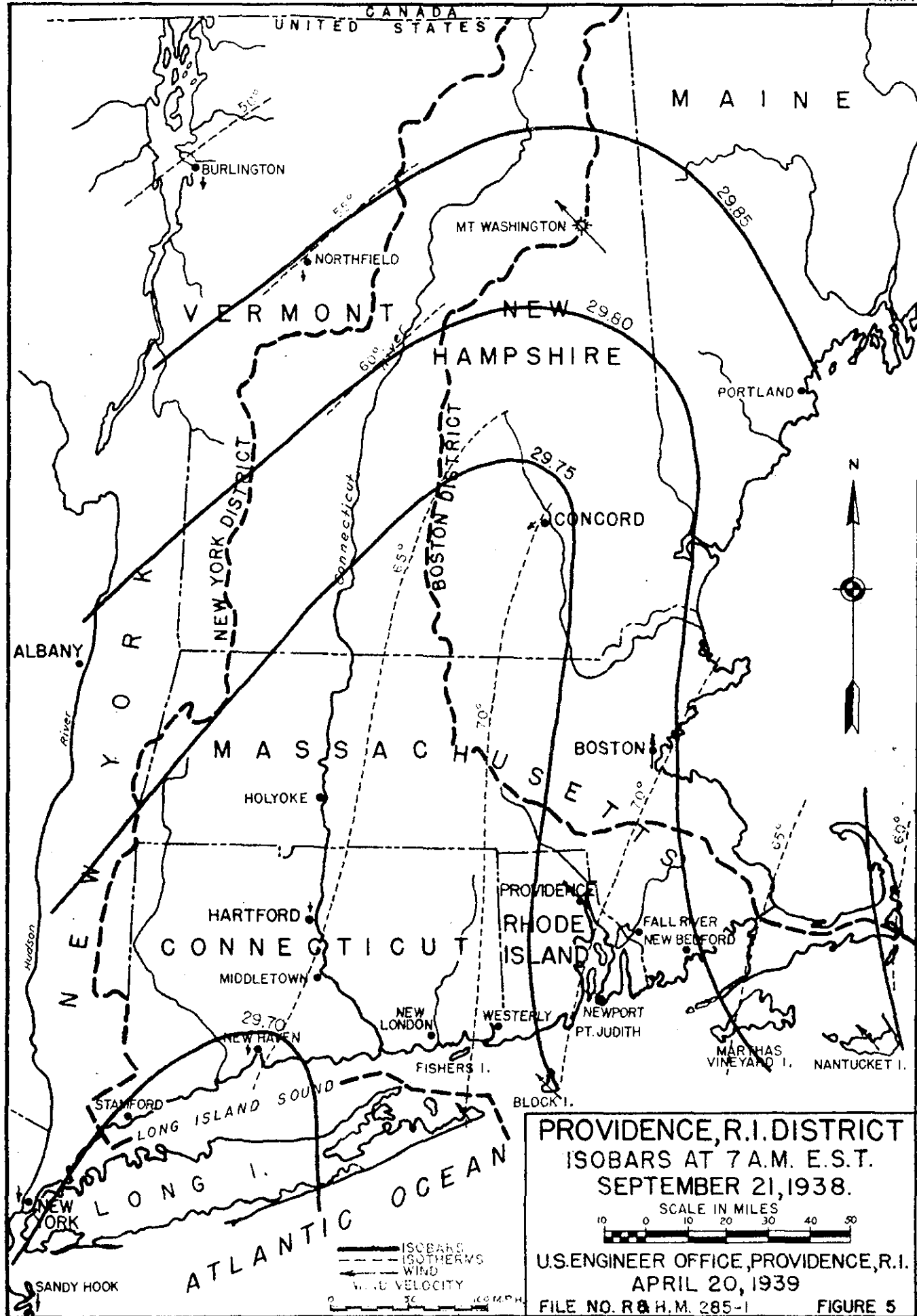
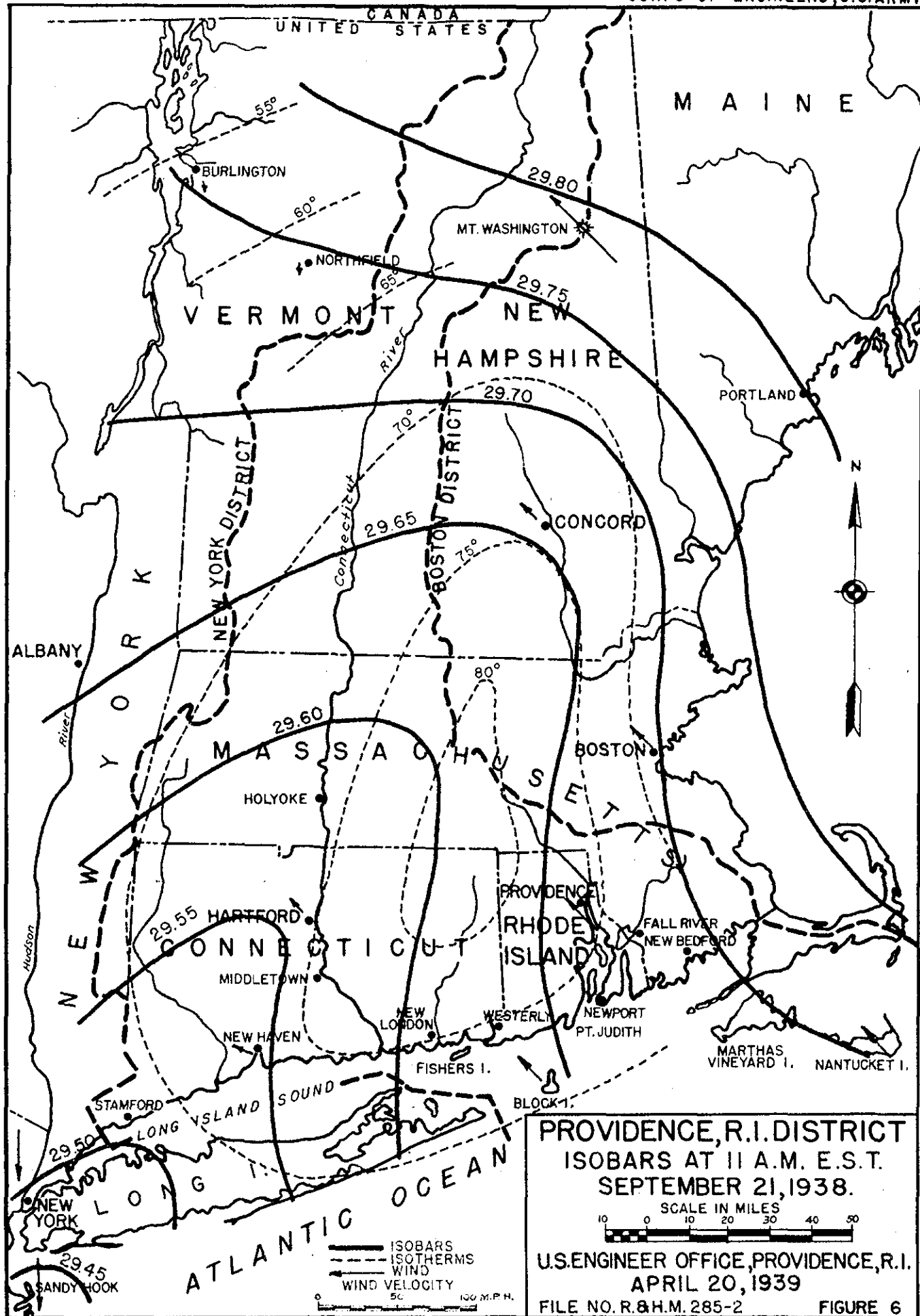
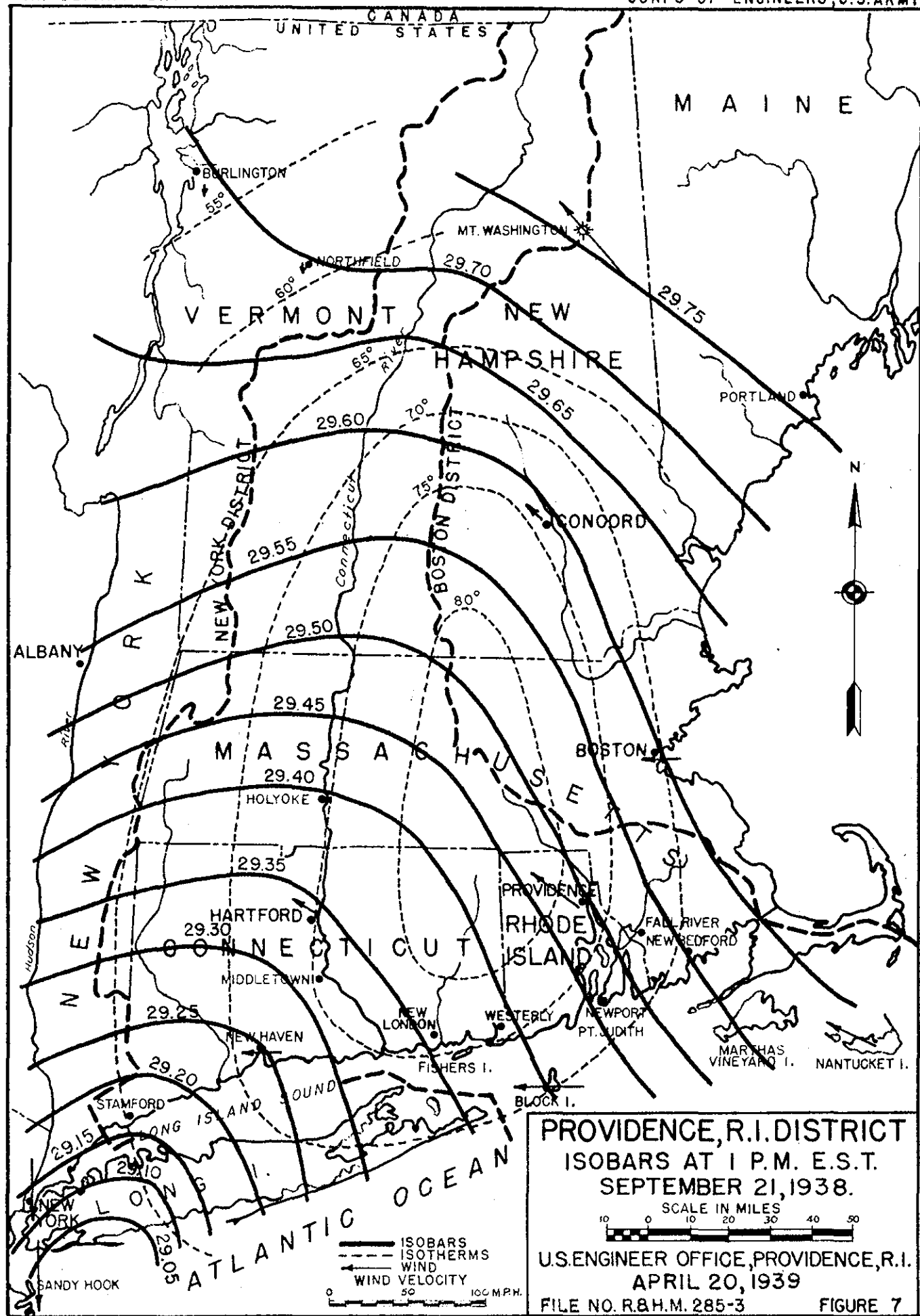


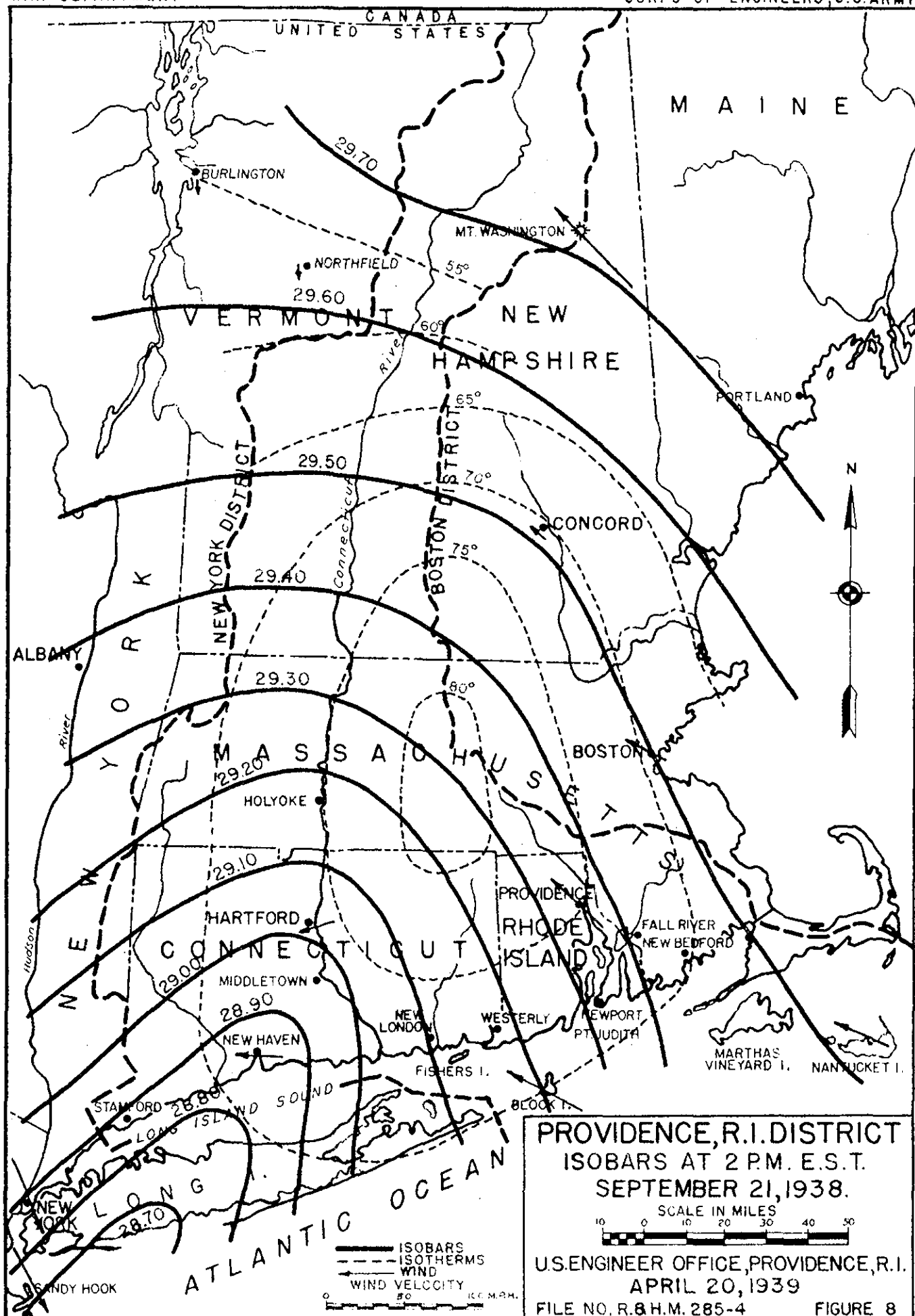
FIGURE 3

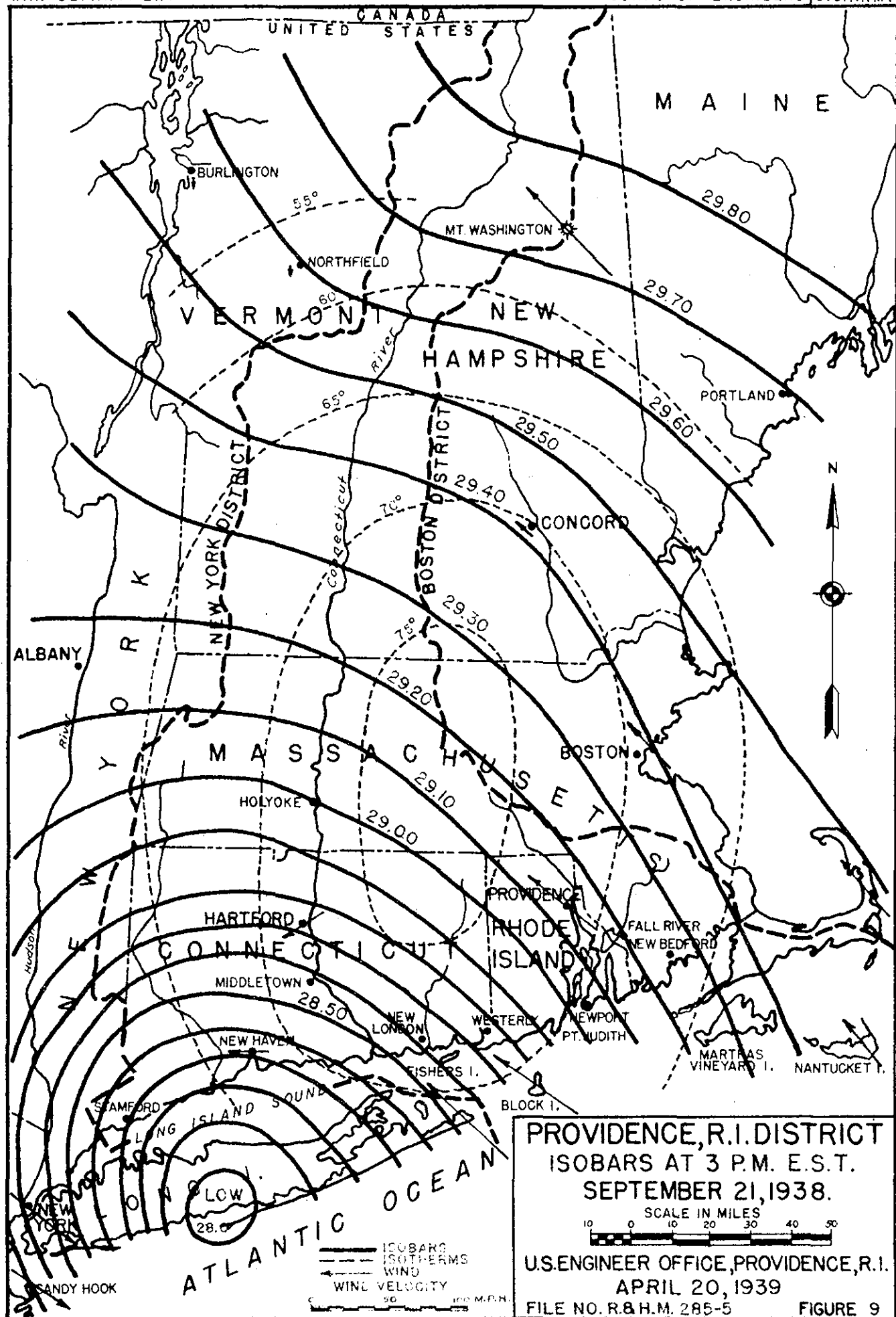


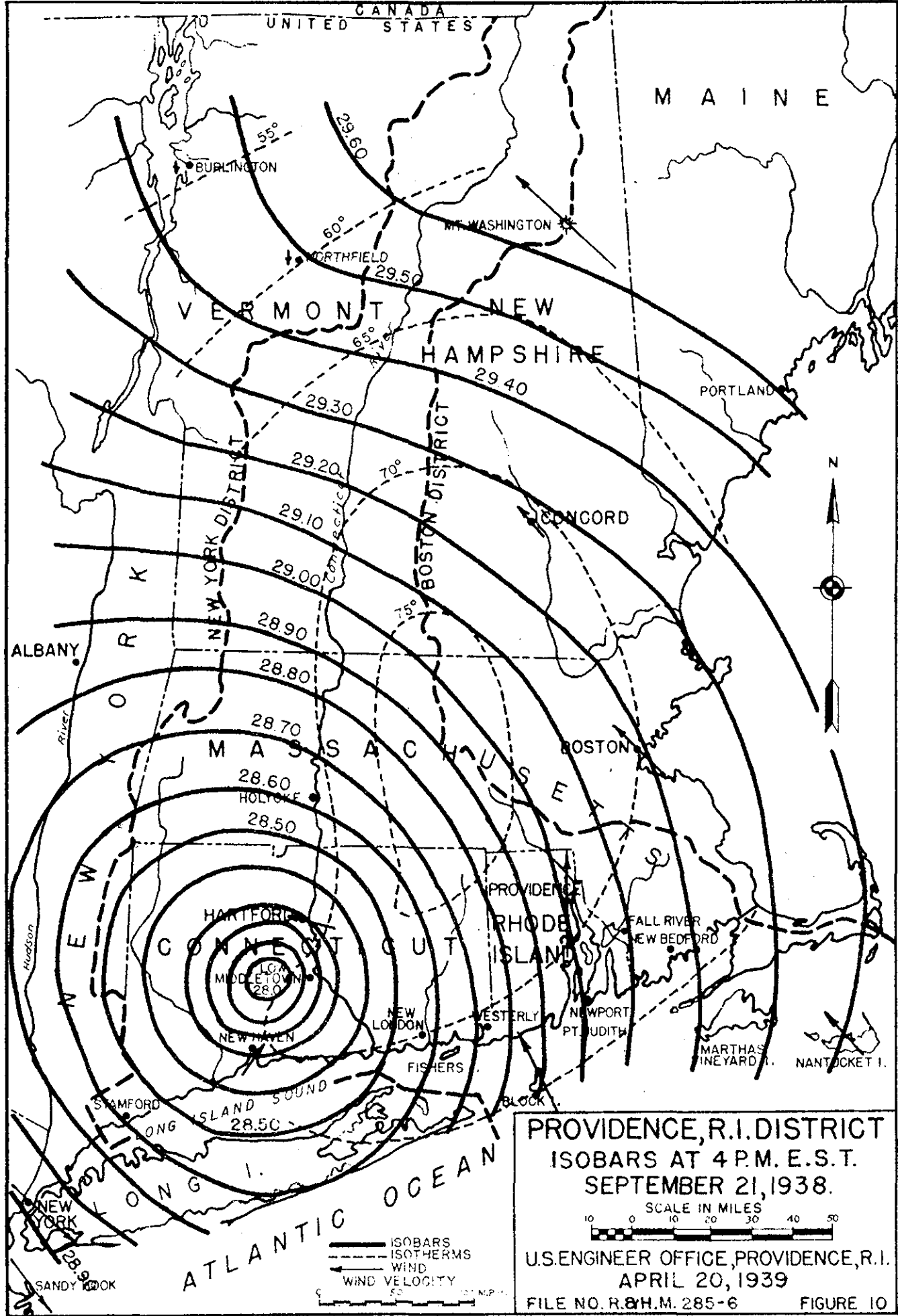


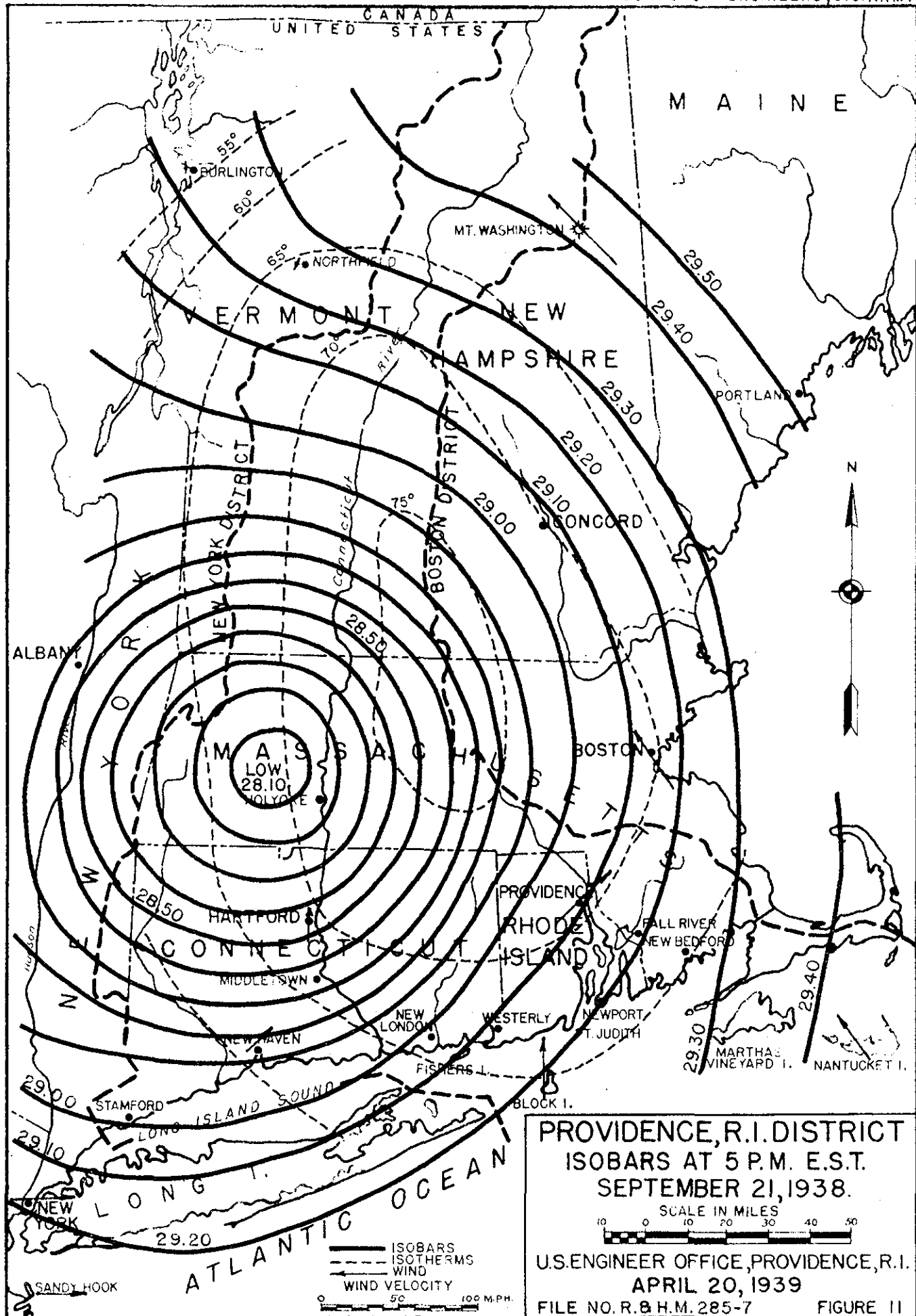


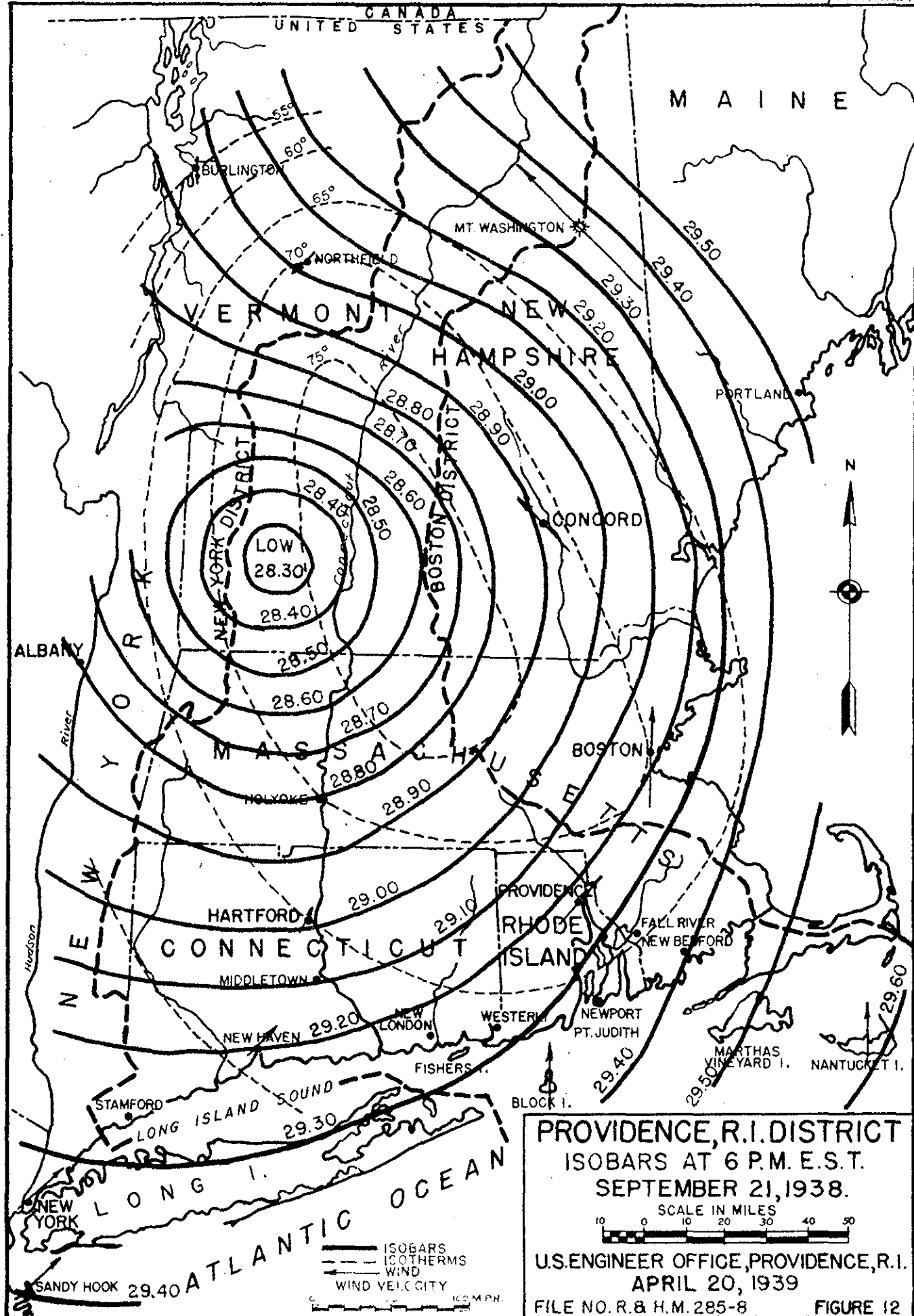


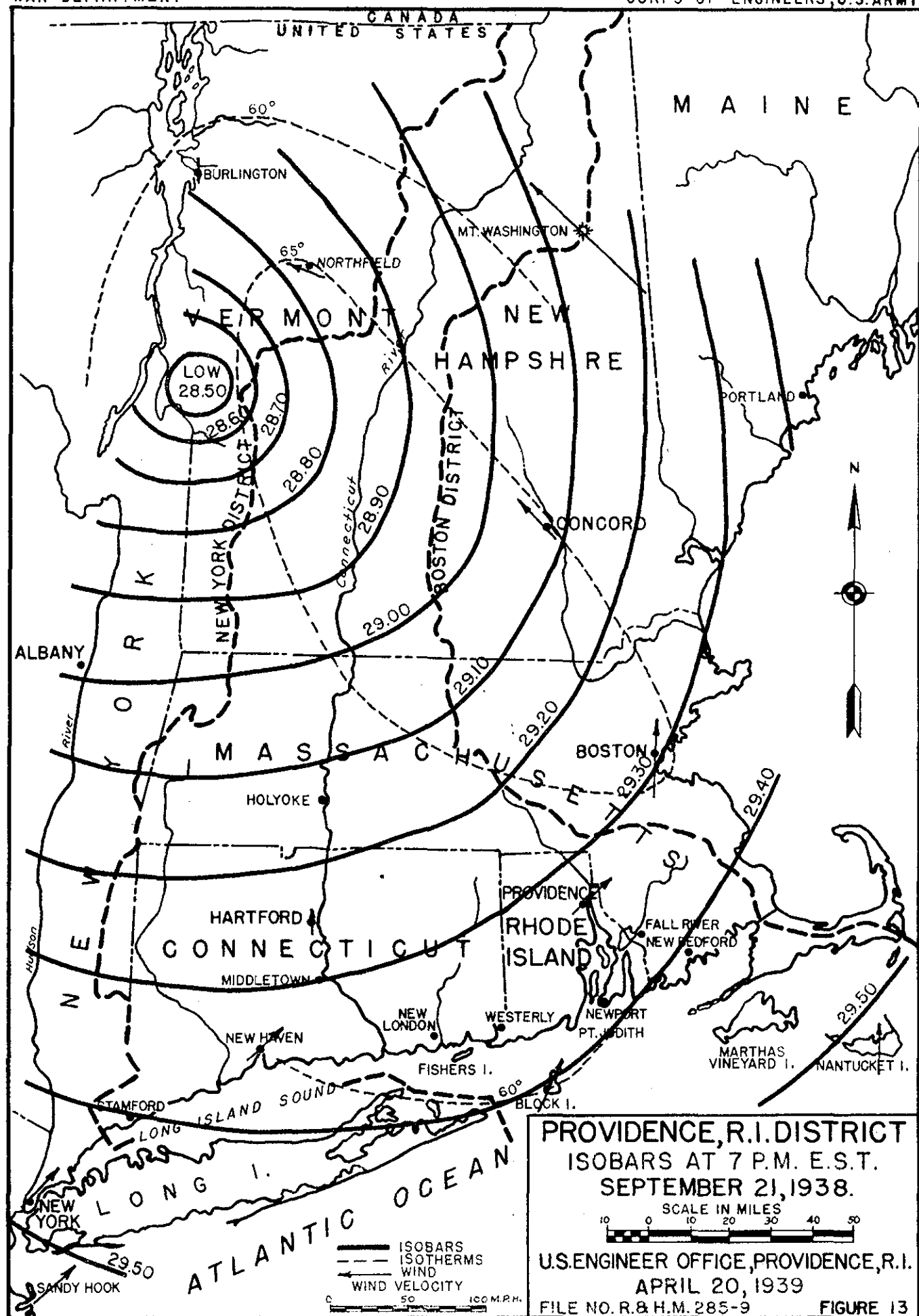


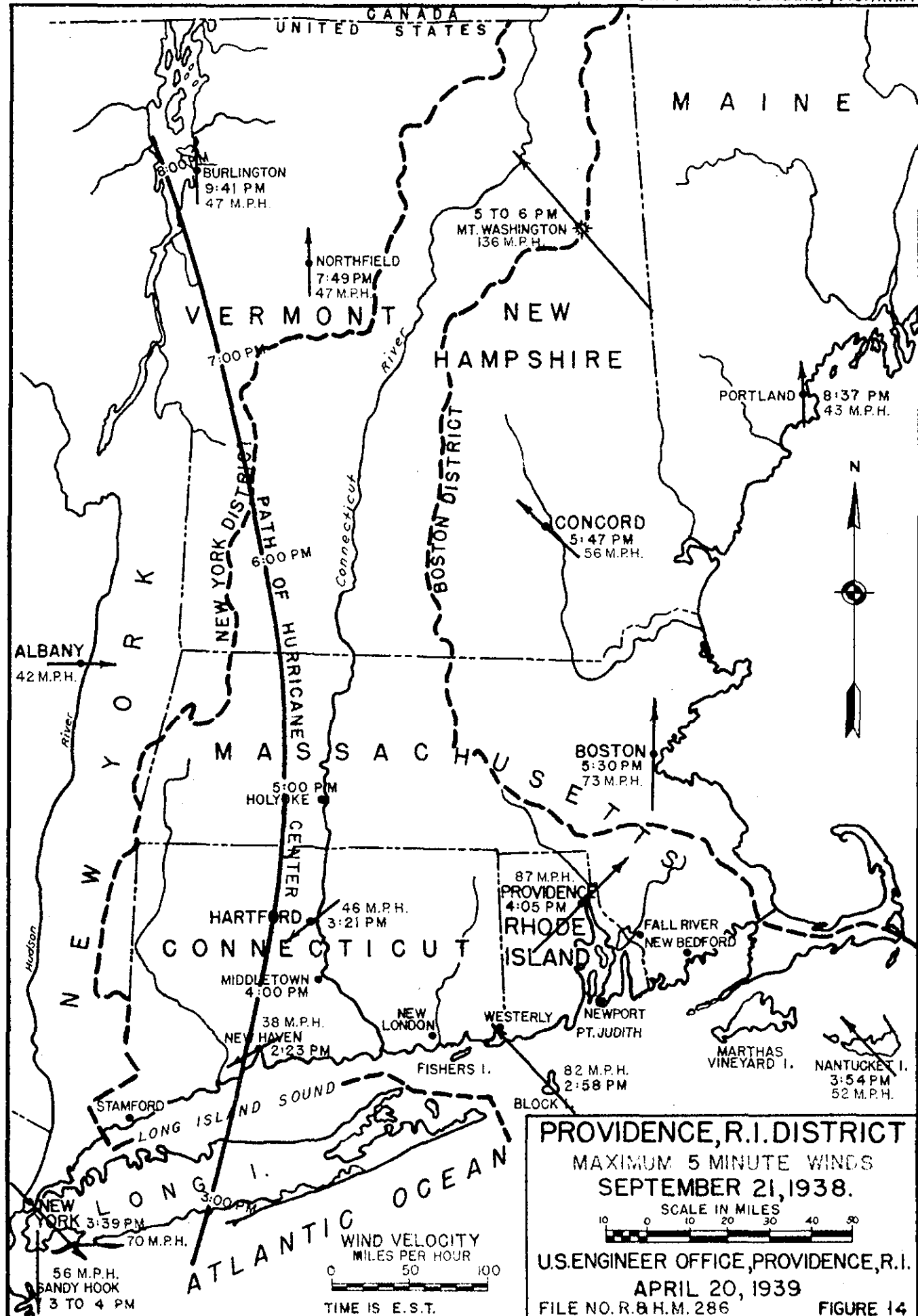


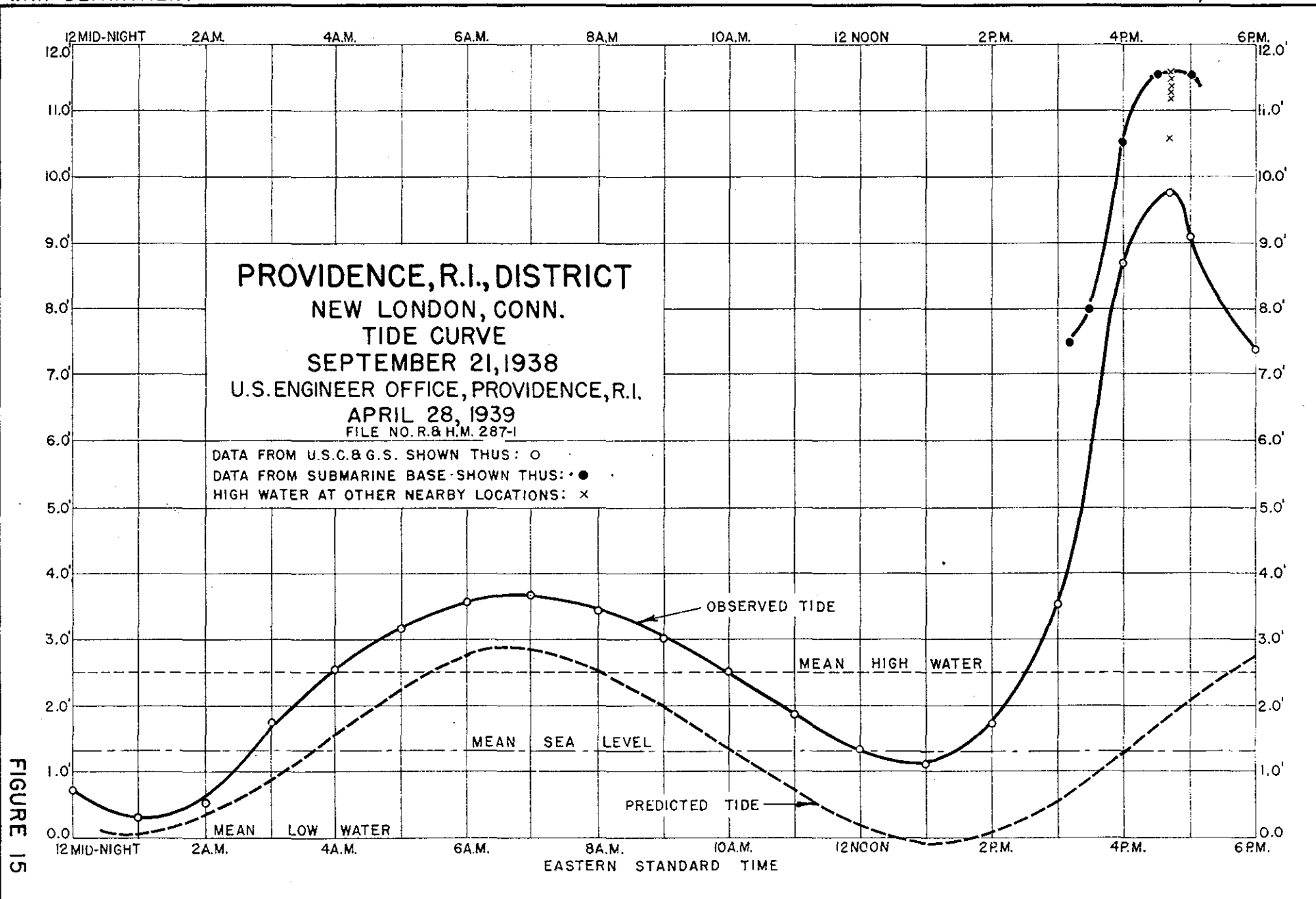












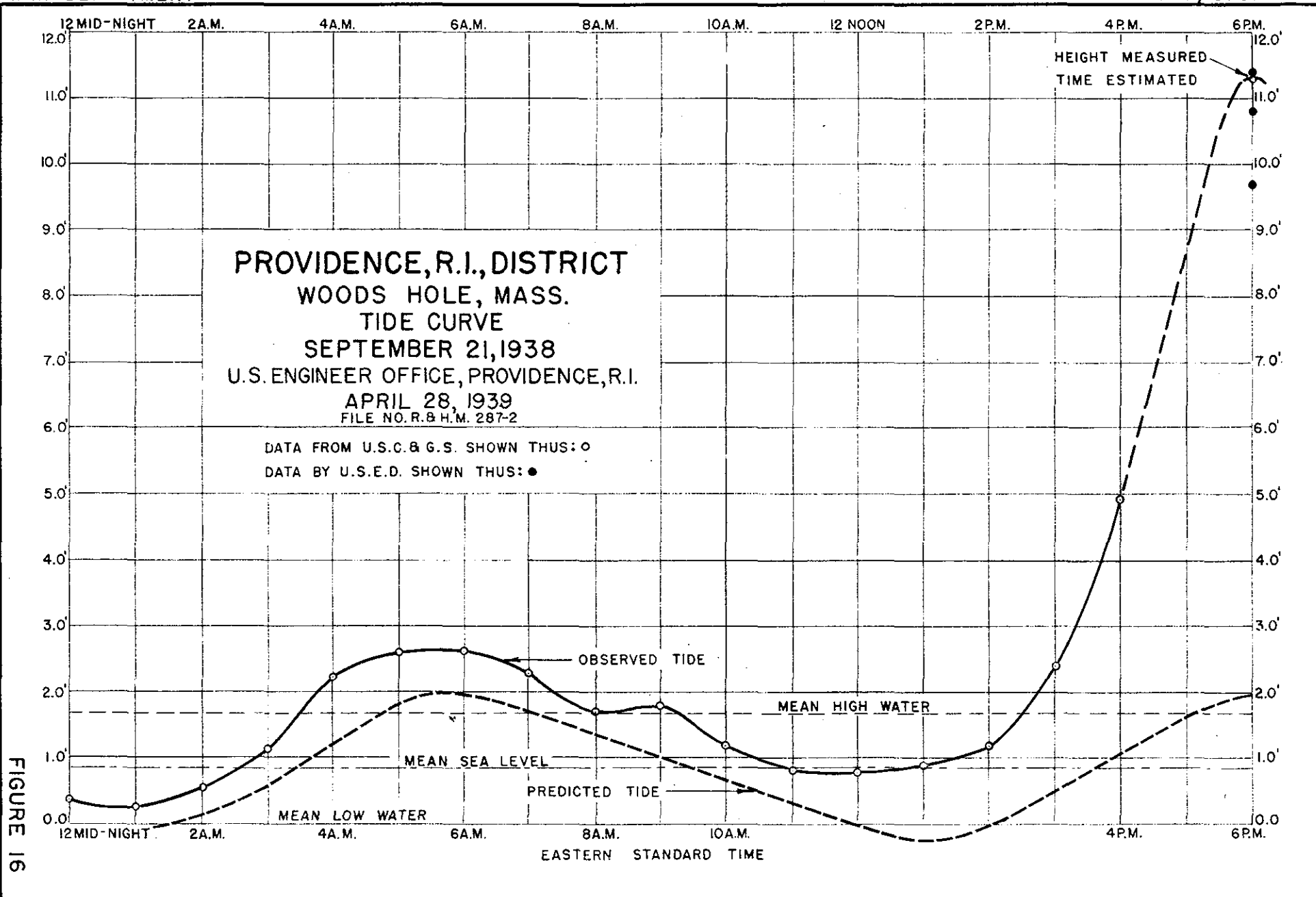
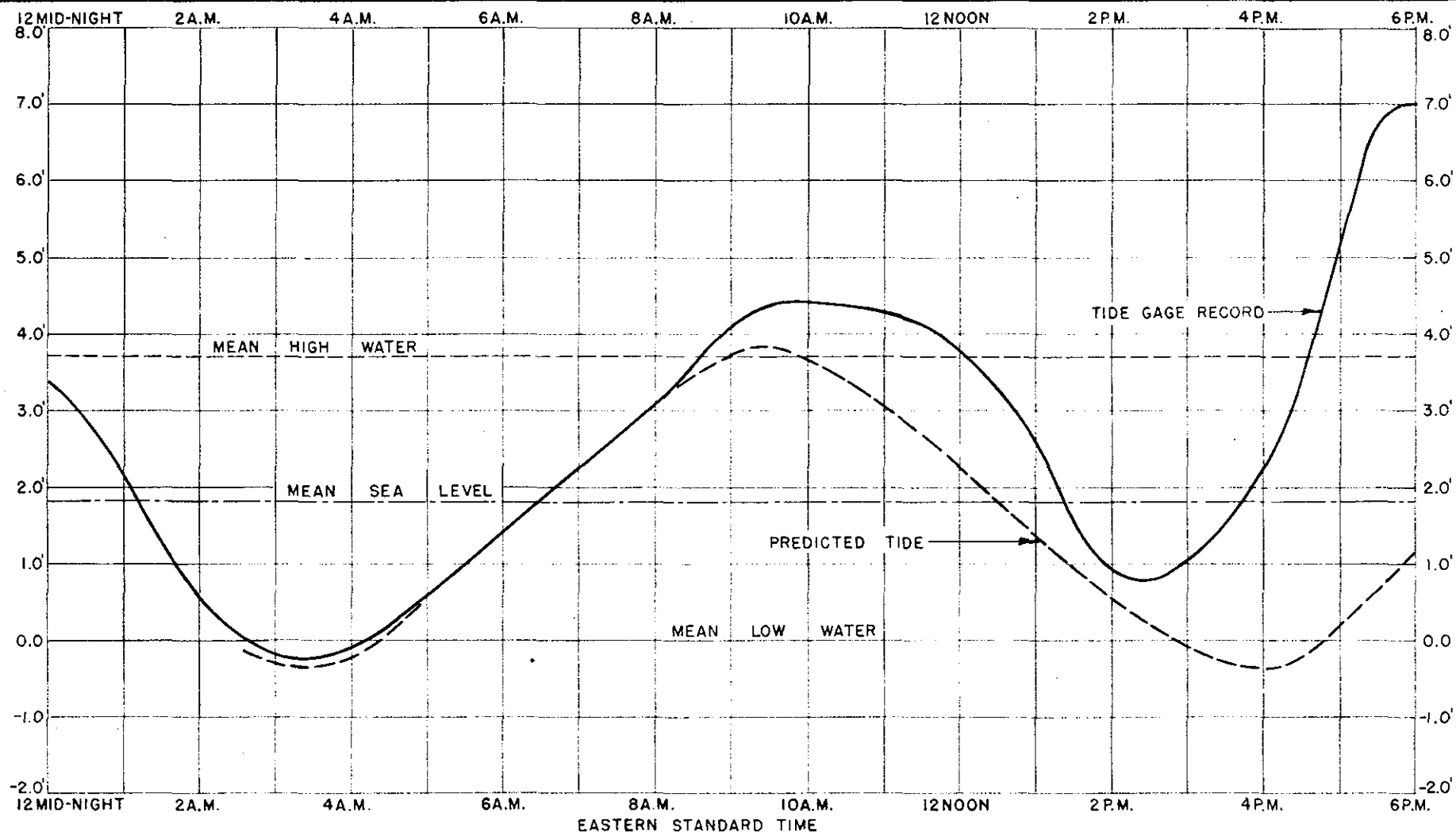


FIGURE 16

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



PROVIDENCE, R.I., DISTRICT
HARWICH, MASS.

TIDE CURVE

SEPTEMBER 21, 1938

U.S. ENGINEER OFFICE, PROVIDENCE, R.I.
APRIL 28, 1939 FILE NO. R&H.M. 287-3

FIGURE 17

TIDE GAGE LOCATED AT WITCHMERE HARBOR

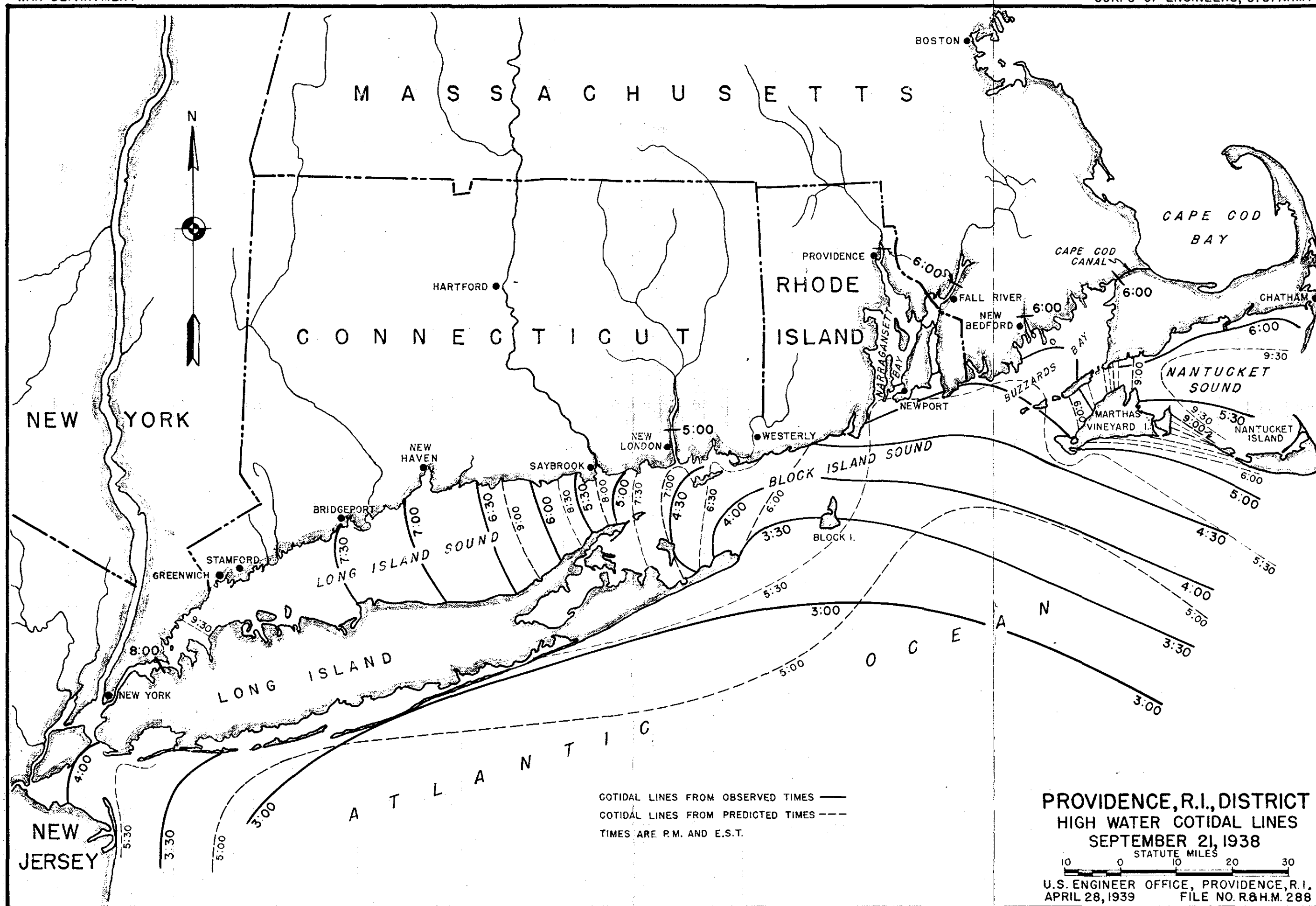
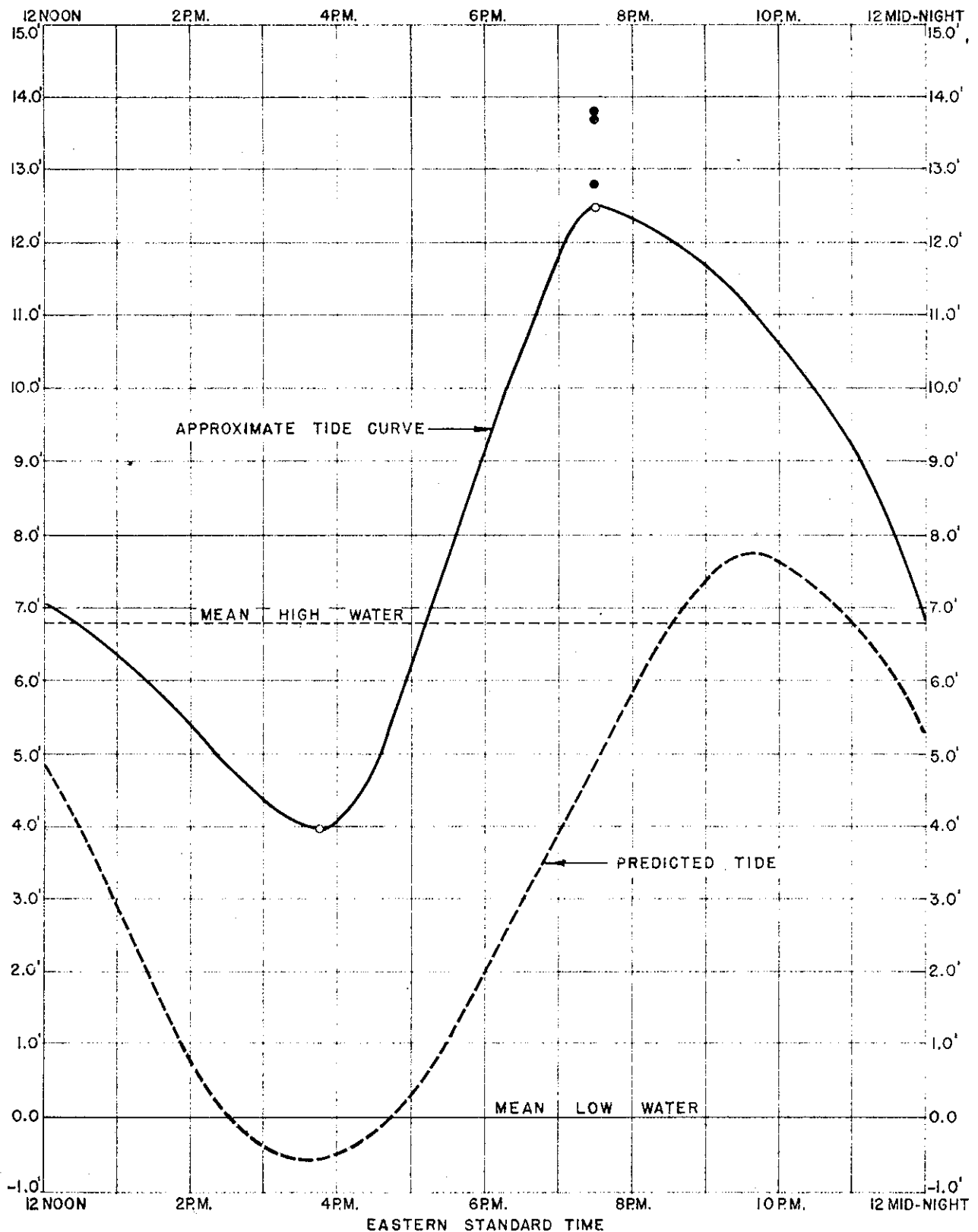


FIGURE 18



OBSERVED HEIGHTS SHOWN THUS:

YELLOW MILL BRIDGE ○

OTHER LOCATIONS •

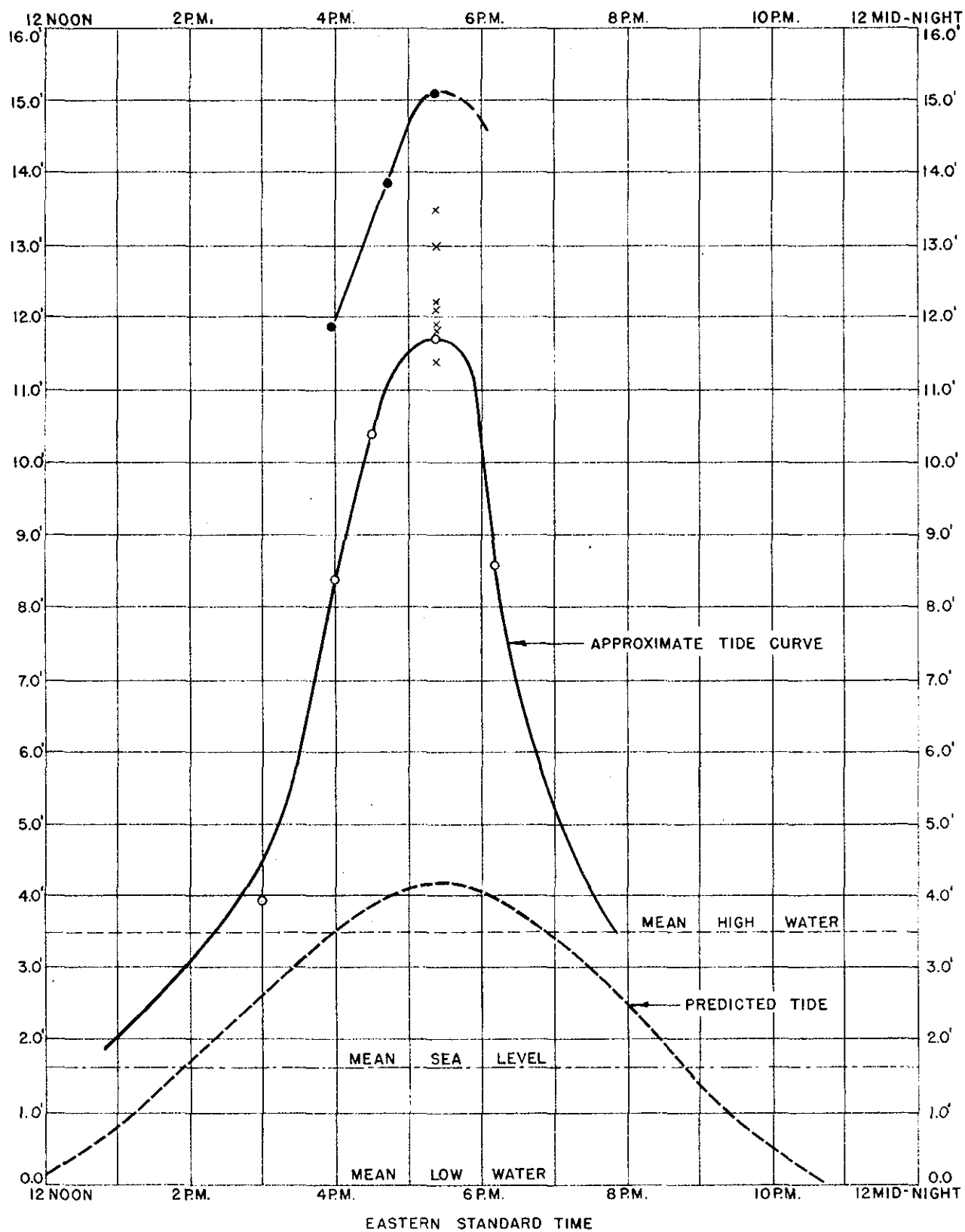
PROVIDENCE, R.I., DISTRICT
BRIDGEPORT, CONN.

TIDE CURVE

SEPTEMBER 21, 1938

U.S. ENGINEER OFFICE, PROVIDENCE, R.I.
APRIL 28, 1939 FILE NO. R&H.M. 287-4

FIGURE 19



OBSERVED HEIGHTS SHOWN THUS:

NEWPORT HARBOR ○

NAVAL TORPEDO STATION GOAT I. ●

OTHER LOCATIONS ×

PROVIDENCE, R.I., DISTRICT

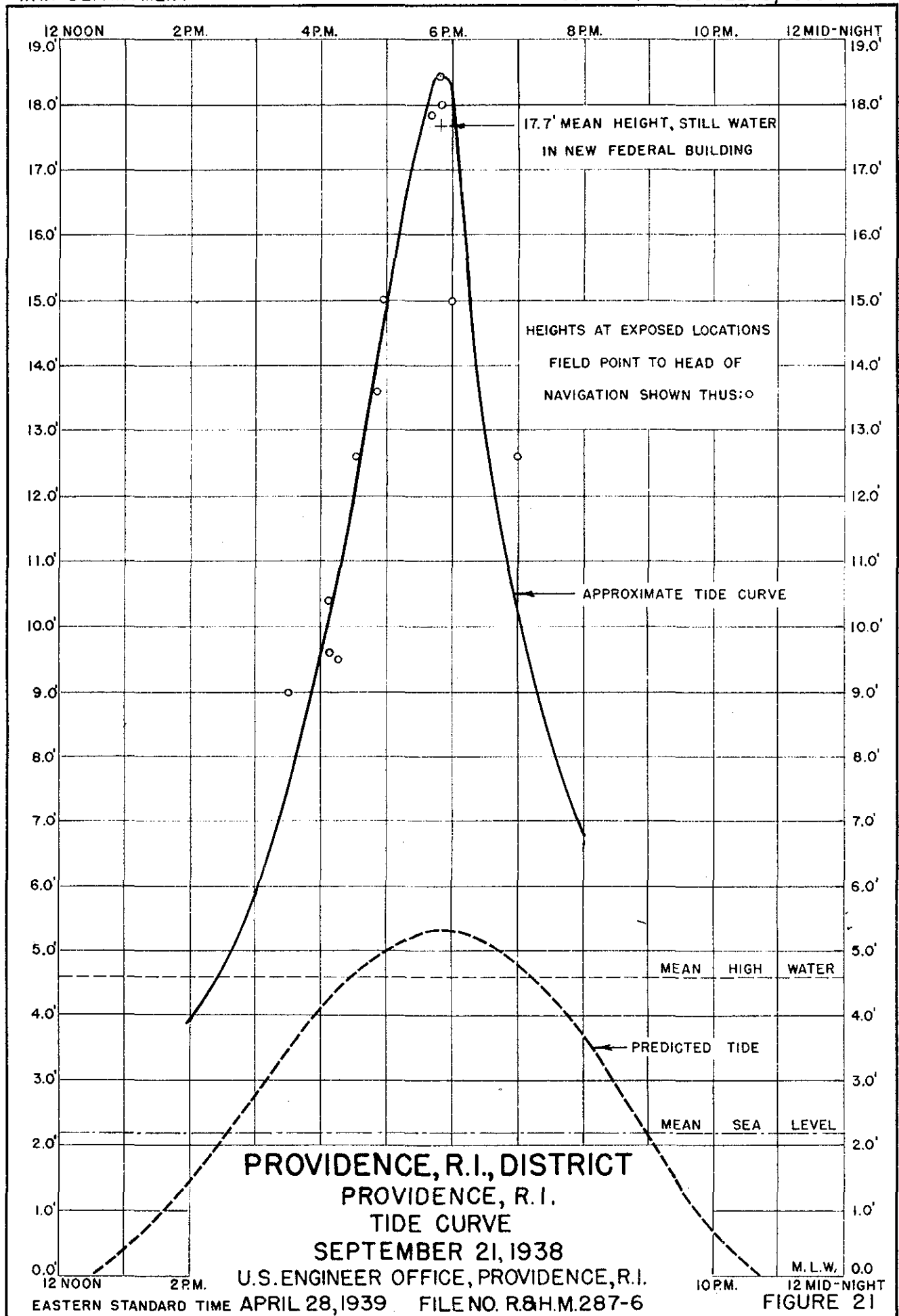
NEWPORT, R.I.

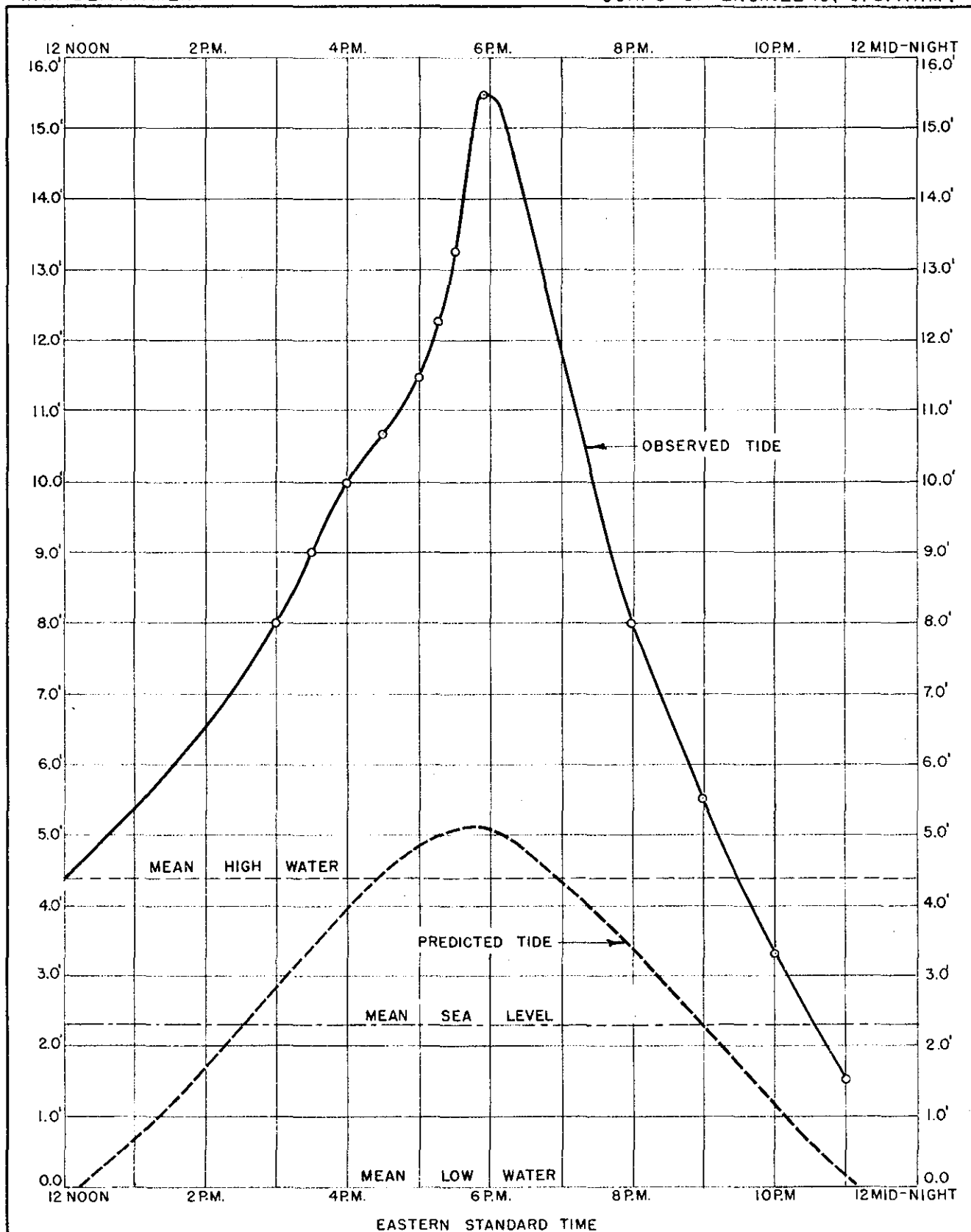
TIDE CURVE

SEPTEMBER 21, 1938

U.S. ENGINEER OFFICE, PROVIDENCE, R.I.

APRIL 28, 1939 FILE NO. R&H.M. 287-5





DATA FROM MONTAUP ELECTRIC CO.

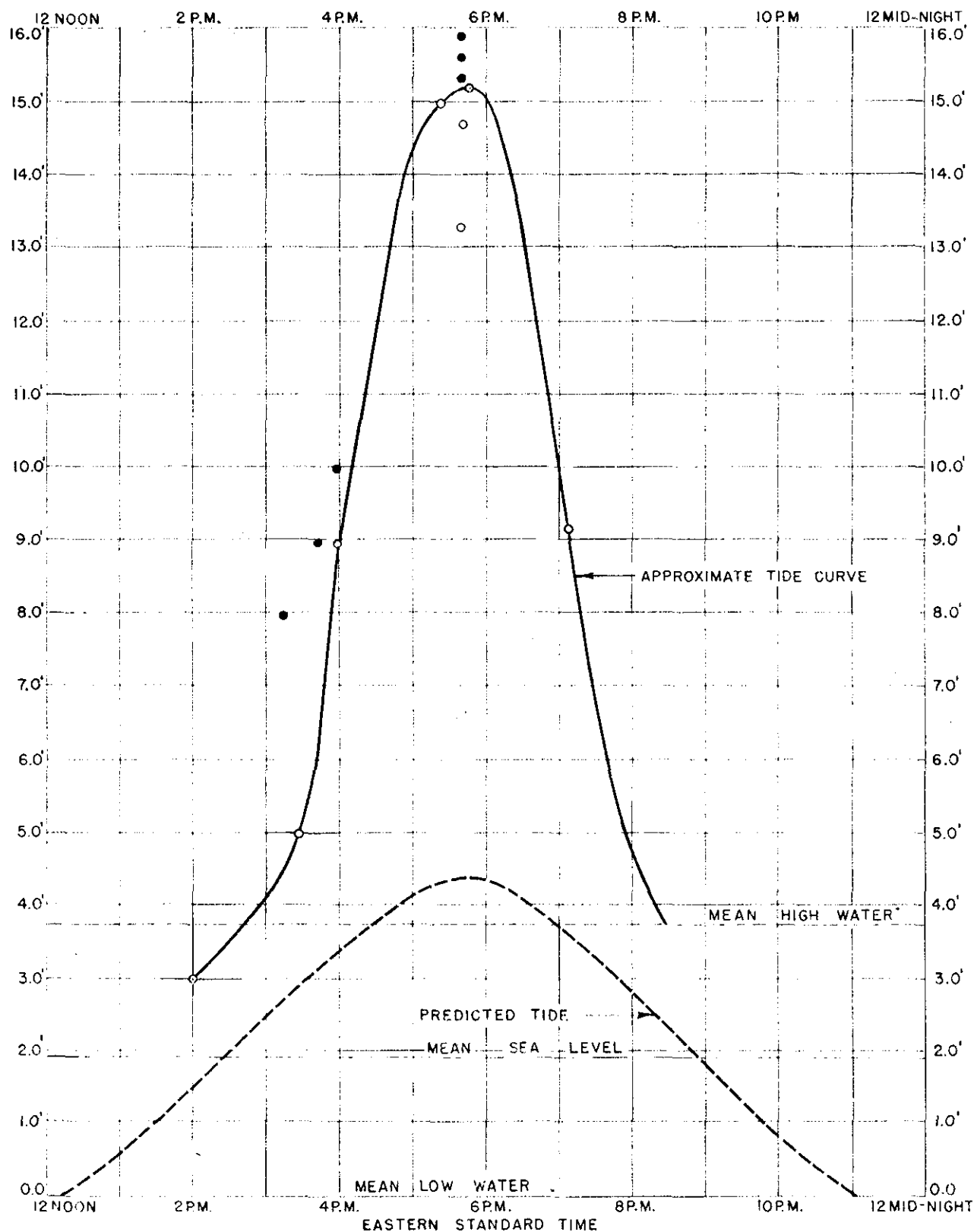
SHOWN THUS ○

**PROVIDENCE, R.I., DISTRICT
SOMERSET, MASS.****TIDE CURVE****SEPTEMBER 21, 1938**

U.S. ENGINEER OFFICE, PROVIDENCE, R.I.

APRIL 28, 1939 FILE NO. R&H.M. 287-7

FIGURE 22



REPORTED HEIGHTS IN SHELTERED LOCATIONS
SHOWN THUS: ○
REPORTED HEIGHTS IN EXPOSED LOCATIONS
SHOWN THUS: ●

PROVIDENCE, R.I., DISTRICT
NEW BEDFORD, MASS.
TIDE CURVE

SEPTEMBER 21, 1938
U.S. ENGINEER OFFICE, PROVIDENCE, R.I.
APRIL 28, 1939 FILE NO. R&H.M. 287-8

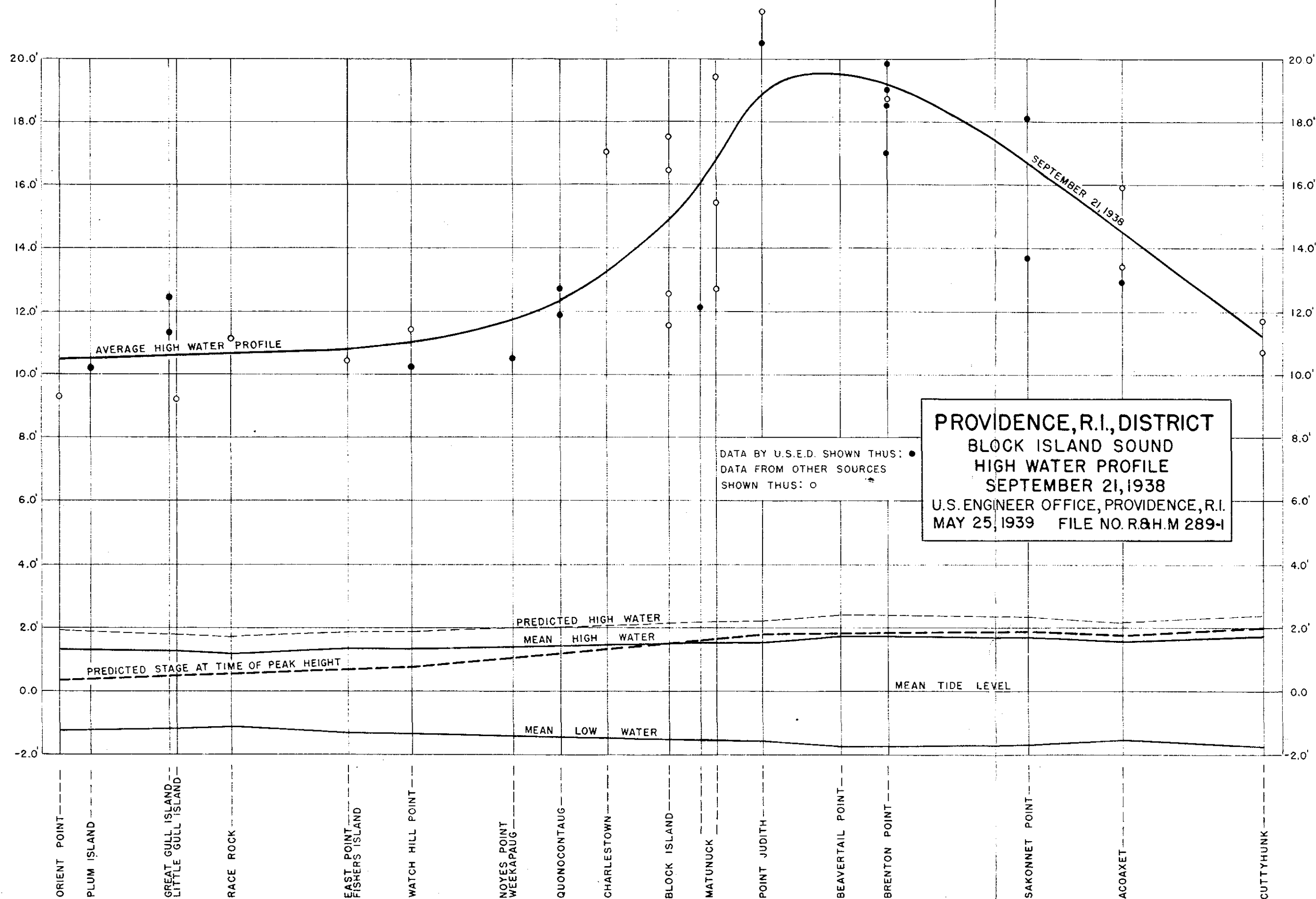
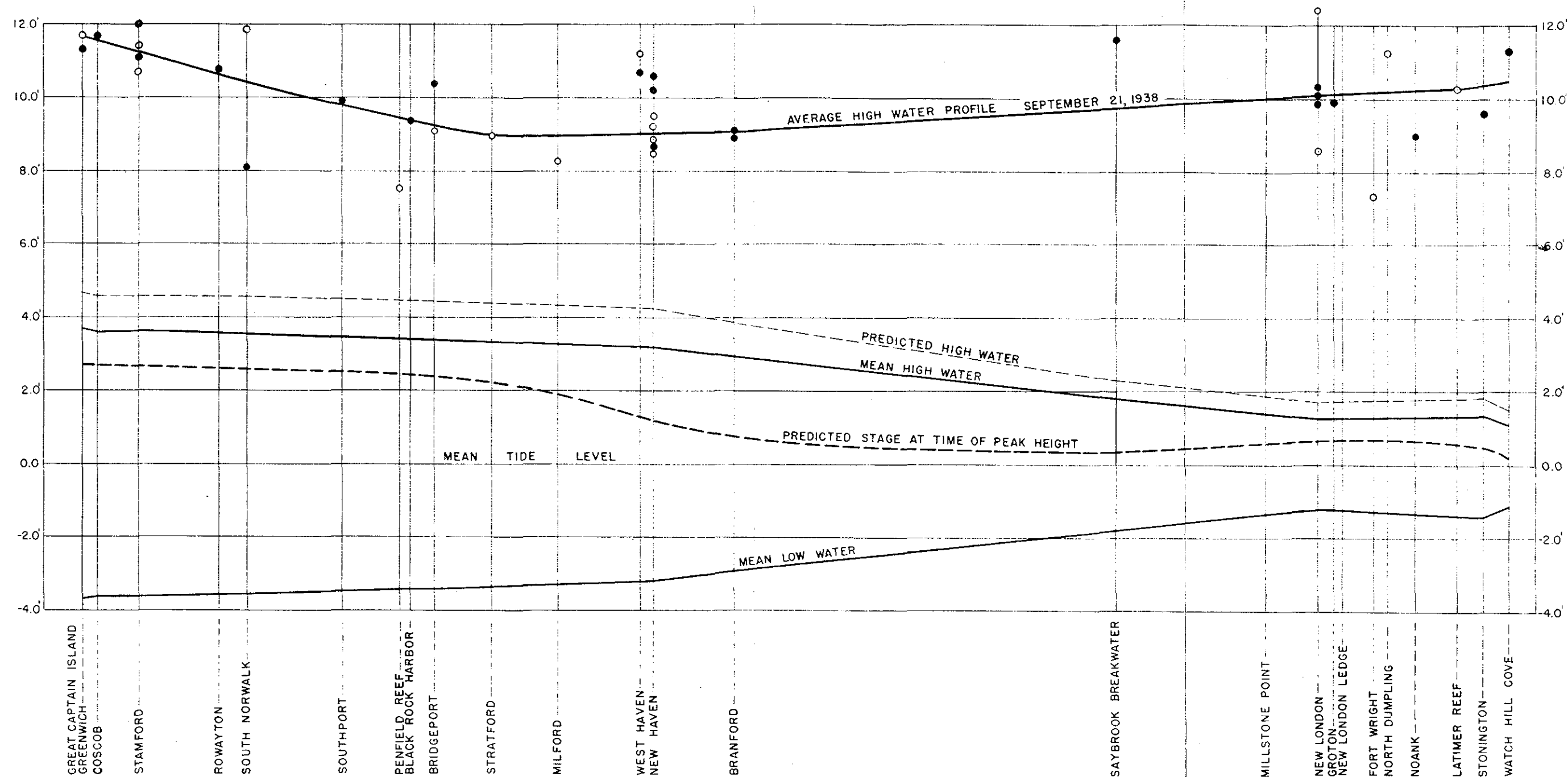


FIGURE 24



PROVIDENCE, R.I., DISTRICT
 LONG ISLAND SOUND
 HIGH WATER PROFILE
 SEPTEMBER 21, 1938
 U.S. ENGINEER OFFICE, PROVIDENCE, R.I.
 MAY 25, 1939 FILE NO. R.&H.M. 289-2

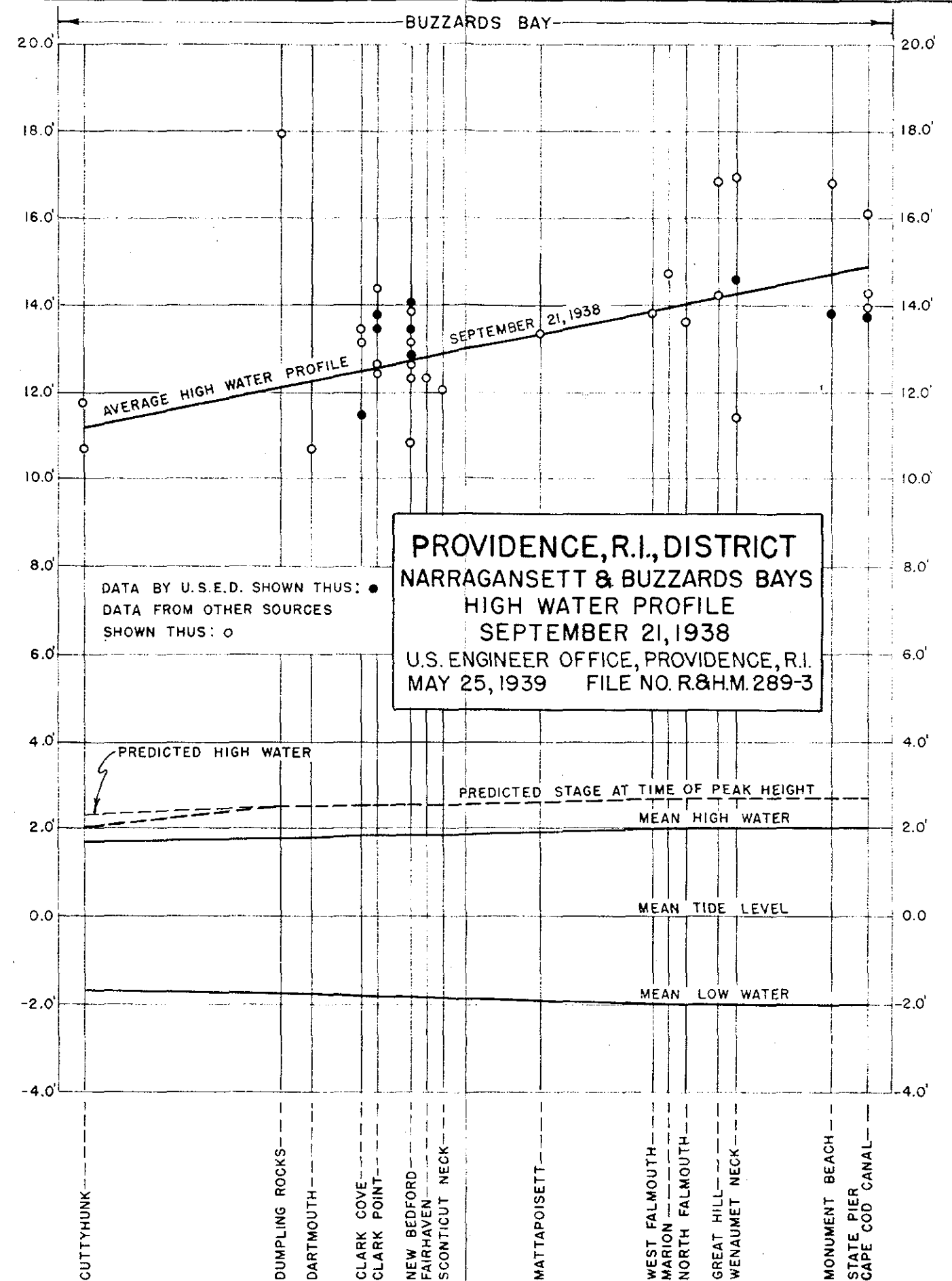
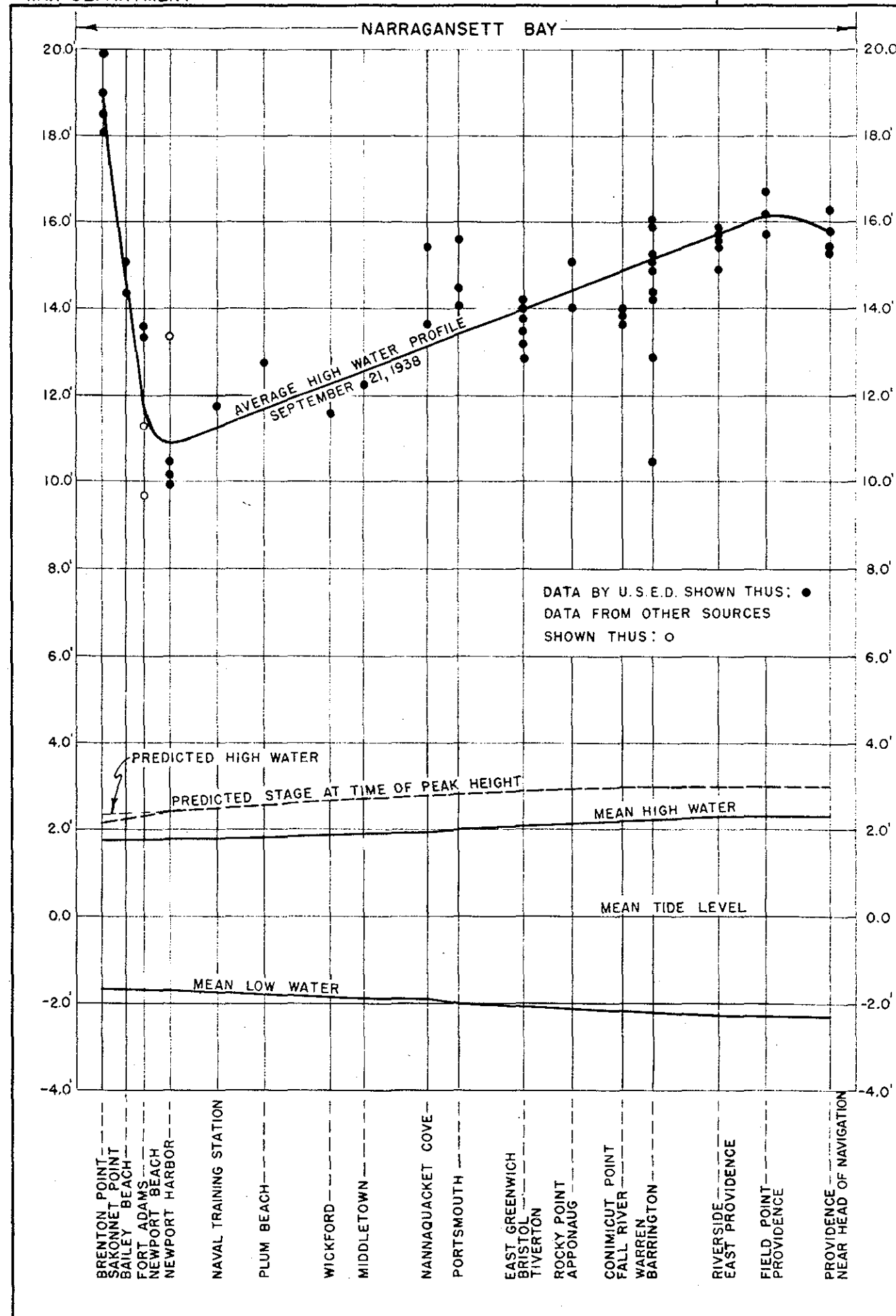
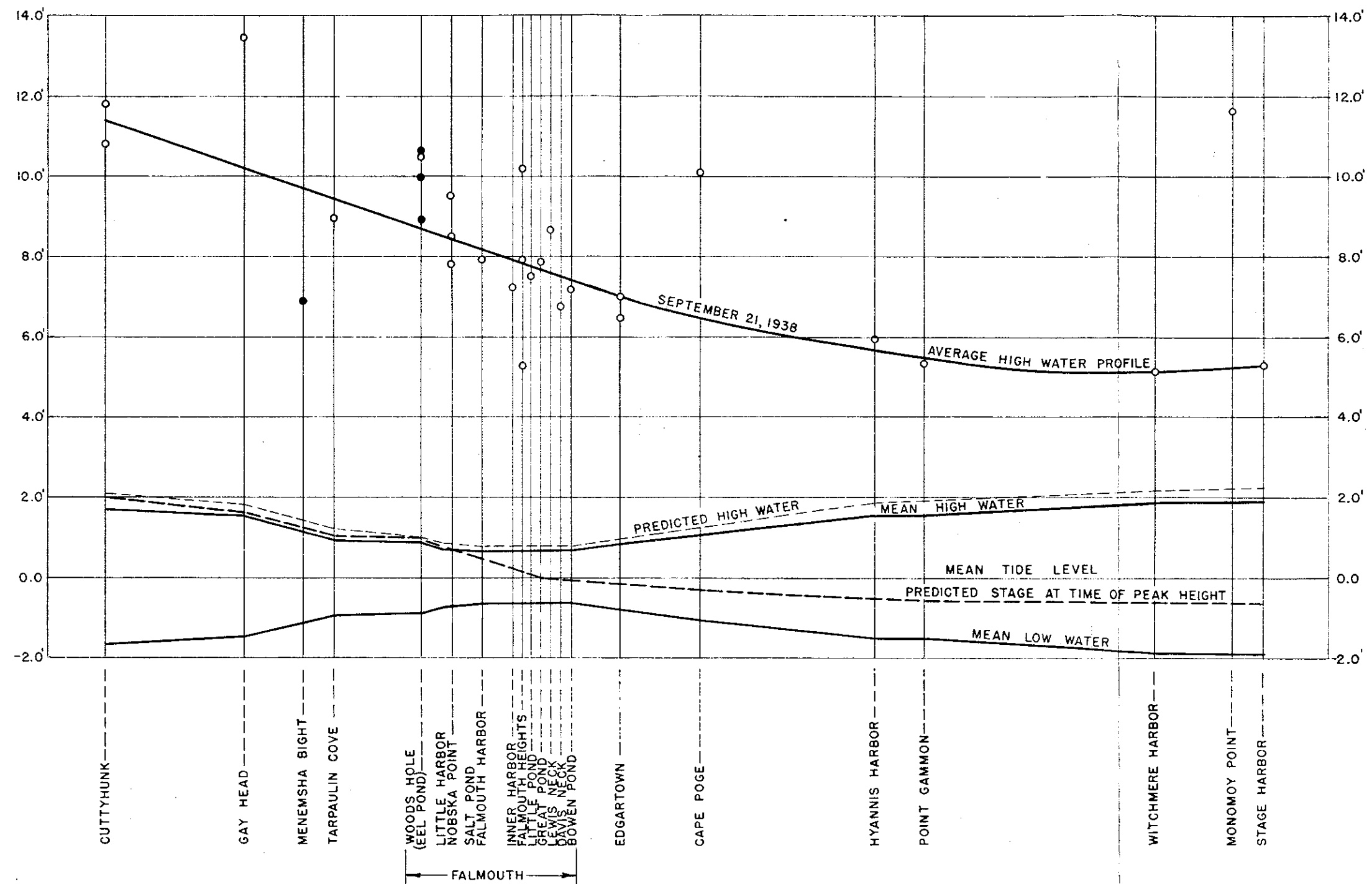


FIGURE 26



DATA BY U.S.E.D. SHOWN THUS: ●
DATA FROM OTHER SOURCES SHOWN THUS: ○

PROVIDENCE, R.I., DISTRICT
VINEYARD & NANTUCKET SOUNDS
HIGH WATER PROFILE
SEPTEMBER 21, 1938
U.S. ENGINEER OFFICE, PROVIDENCE, R.I.
MAY 25, 1939 FILE NO. R&H.M.289-4

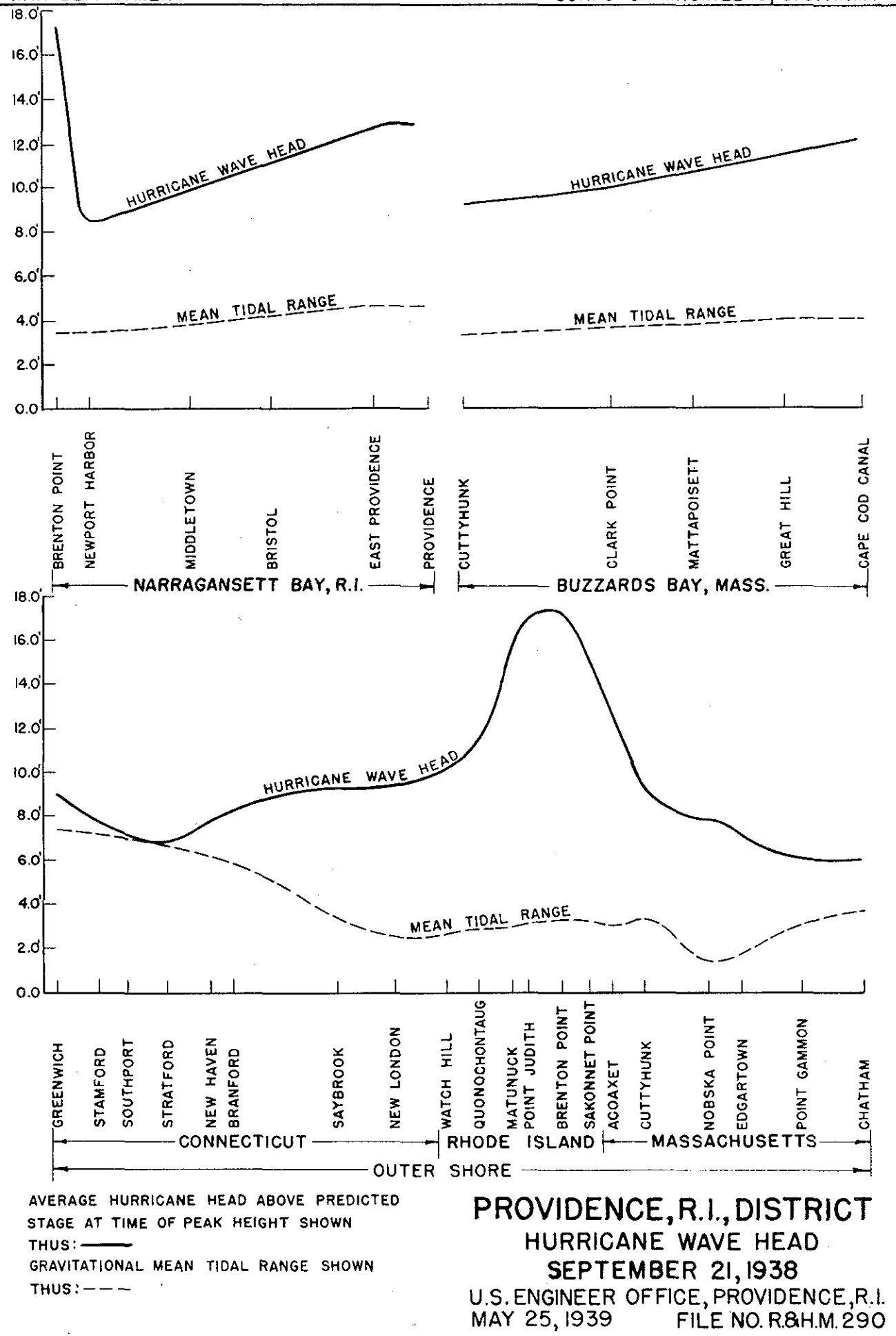
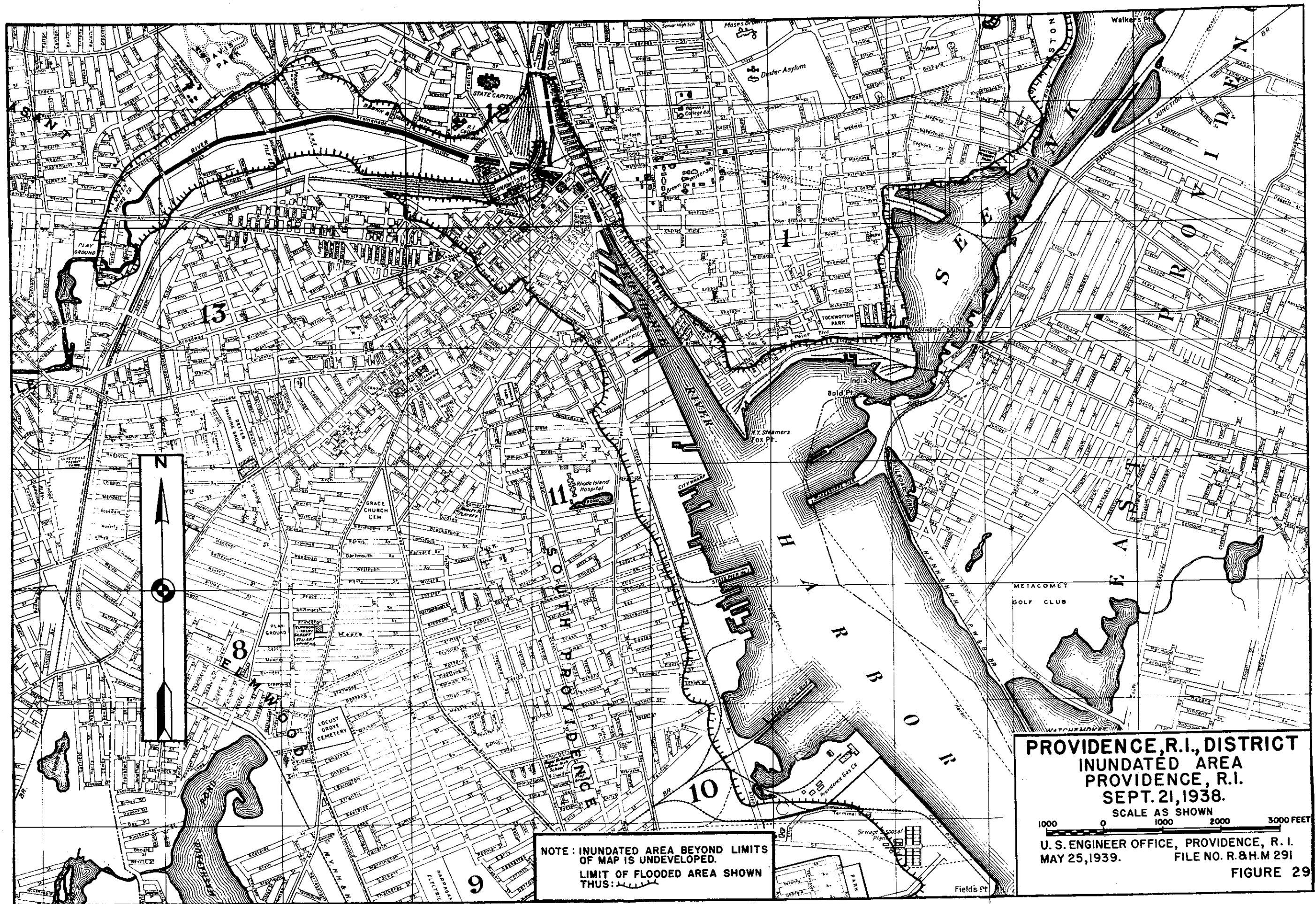


FIGURE 28





Timber damage near Keene, N. H.



Timber damage at Goddard Park, Warwick, R. I.



BEFORE HURRICANE

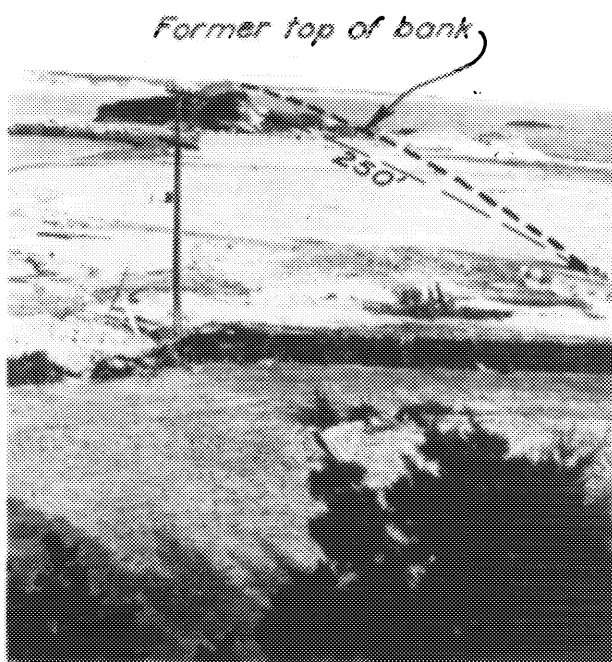


AFTER HURRICANE

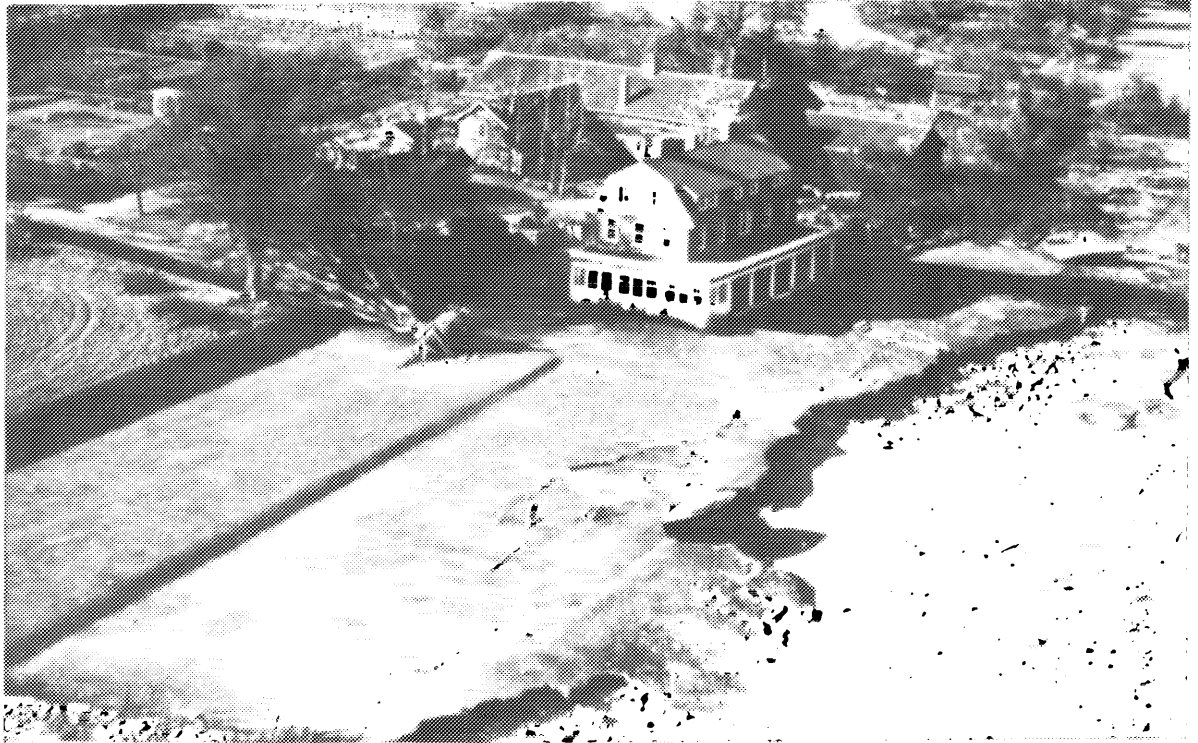
WATCH HILL, WESTERLY, R. I.
Waves eroded headland behind seawall and the splash
floated furniture in house at top of hill.



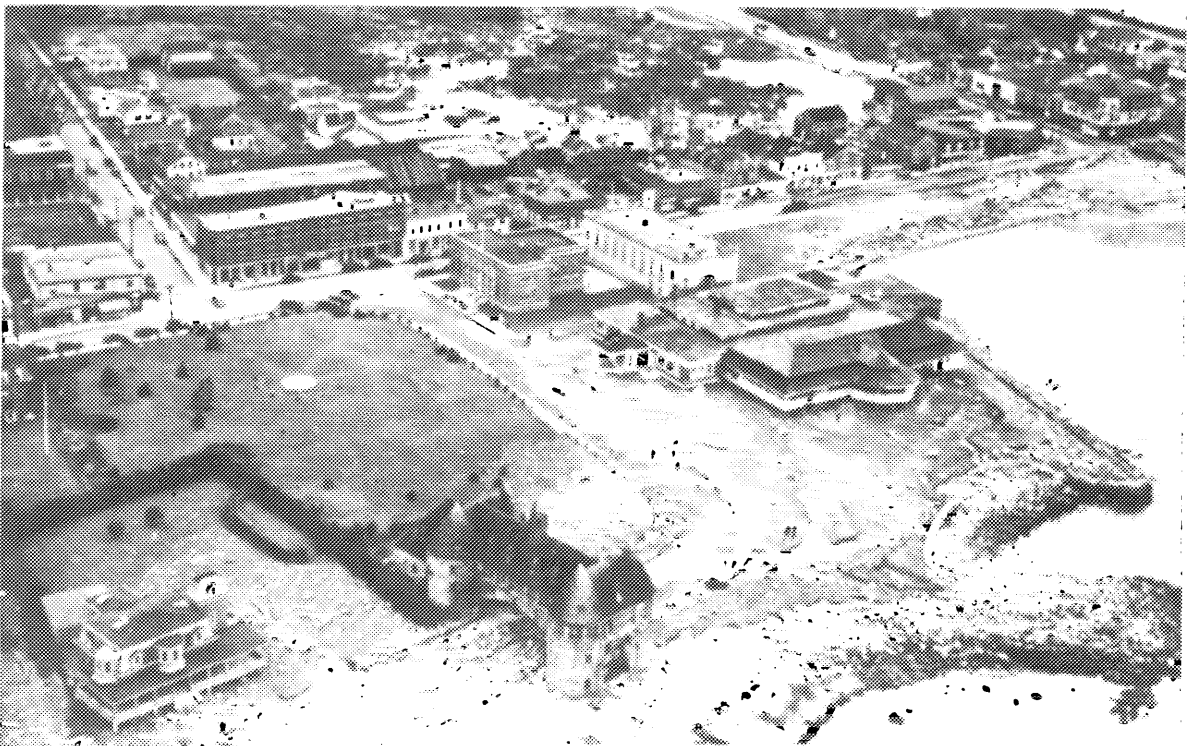
NEWPORT, R. I.
Headland erosion and wash-out of Ten Mile Drive.



ACOAXET, WESTPORT, MASS.
Wash-over and erosion of upland.



WARWICK NECK, R. I.
Trees damaged; upland eroded; boats stranded.



NARRAGANSETT PIER, R. I.
Headland erosion and wash-out of Ocean Drive.



OCEAN GROVE, SWANSEA, MASS. Headland erosion under house. Seawall destruction.

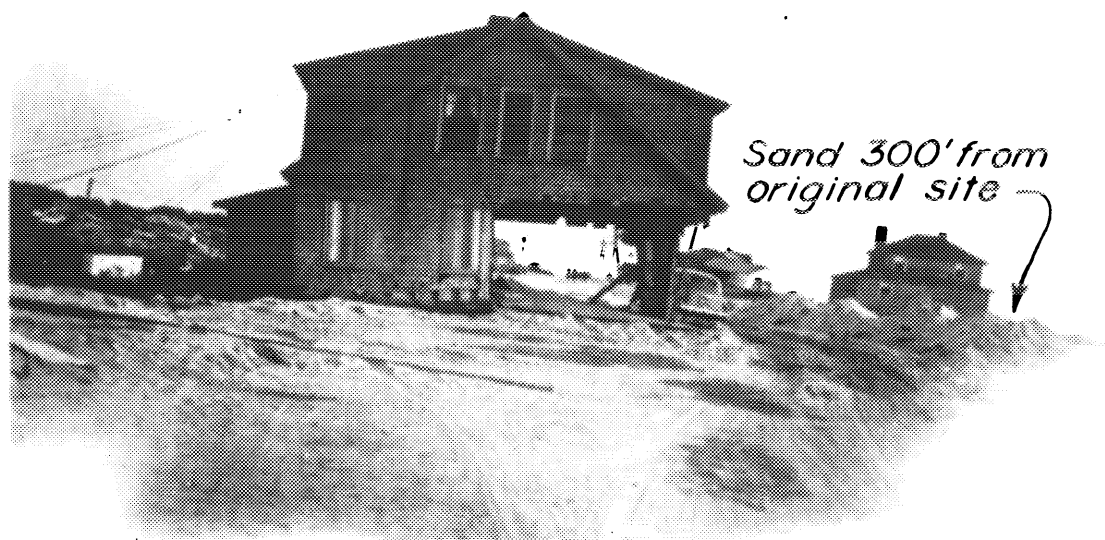


BONNET SHORES, NARRAGANSETT, R. I.
Erosion of sand dune under house.



*Dunes up to 25' high
disappeared*

HORSE NECK BEACH, WESTPORT, MASS.
Sand dunes washed away.



*Sand 300' from
original site*

HORSE NECK BEACH, WESTPORT, MASS.
Sand deposited 300' from former location.

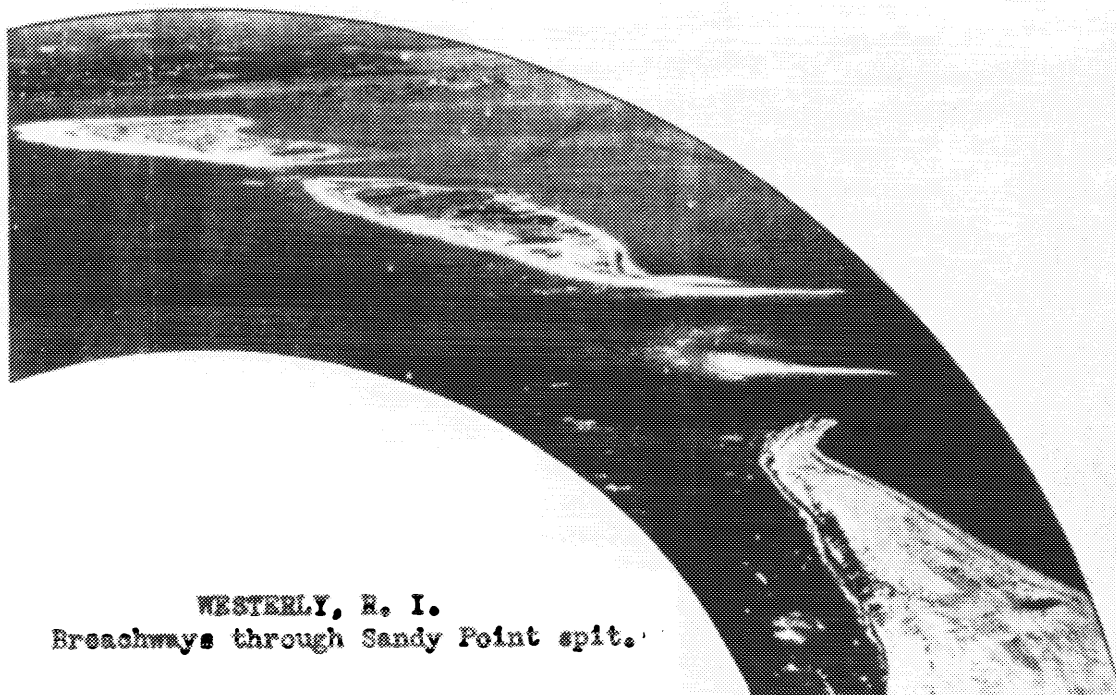


CUTTYHUNK, MASS. Breachway through tombolo.

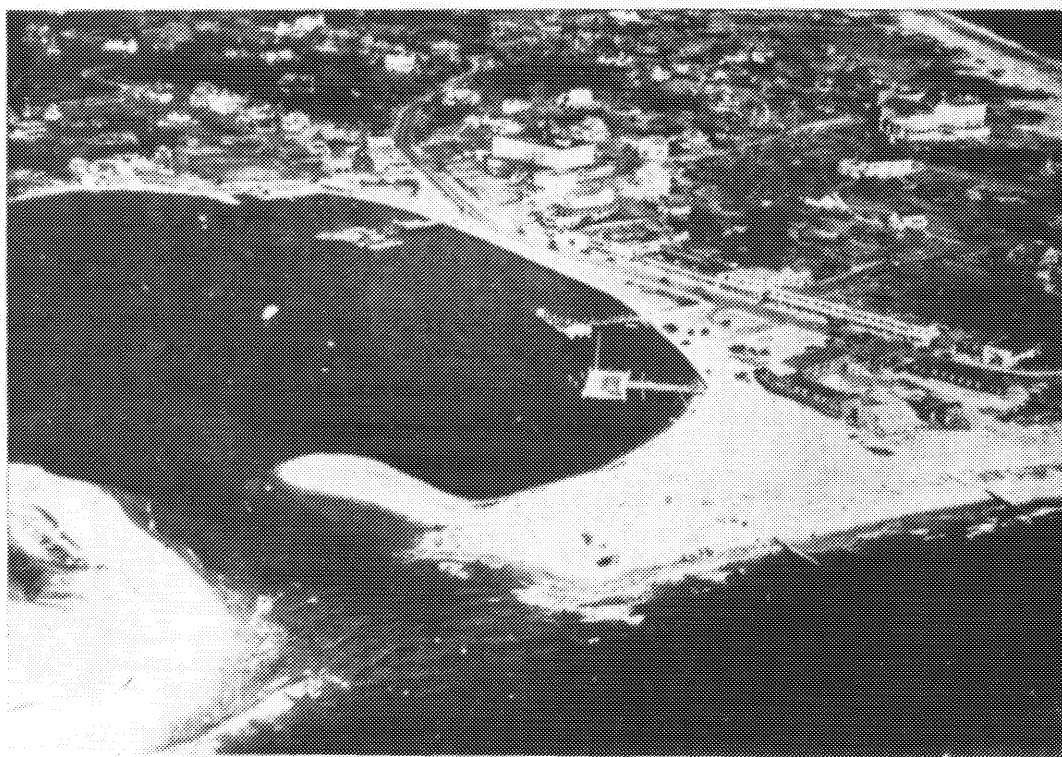


WEEKAPAU, WESTERLY, R. I.

Breachway about 3 x 100 feet through baymouth bar partly filled by natural sand movement two weeks after storm. Wrecked hotel on left.



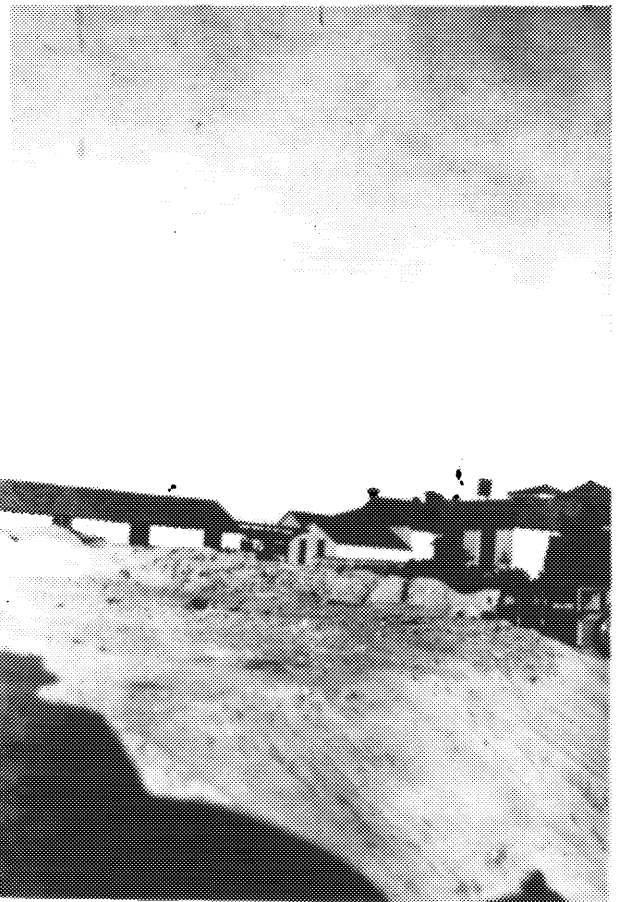
WESTERLY, R. I.
Breachways through Sandy Point spit.



WESTERLY, R. I.
Breachway into Watch Hill Cove through Napatree Point tombolo.



NARRAGANSETT PIER, R. I.
Beach at Dunes Club
eroded 3' to 4' seaward
of buildings.



NARRAGANSETT PIER, R. I.
3' to 4' sand deposited
landward of buildings
at Dunes Club.



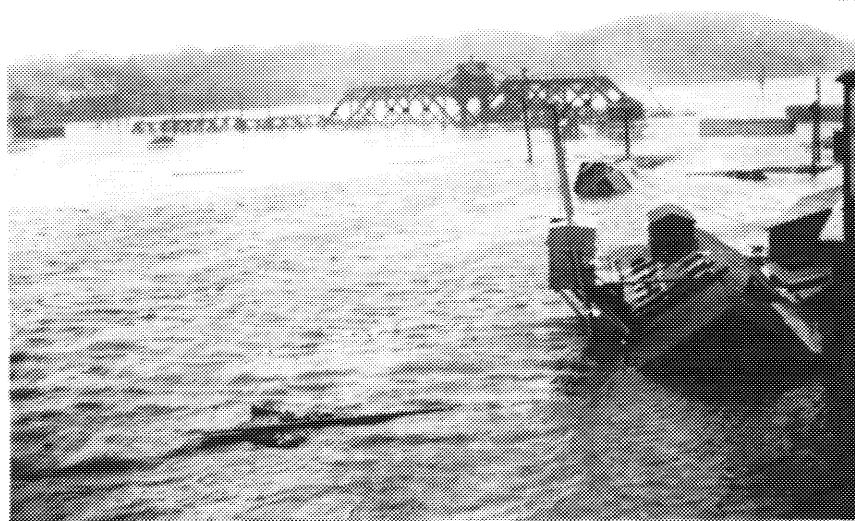
BARRINGTON, R. I.
White Church bridge
swept away.



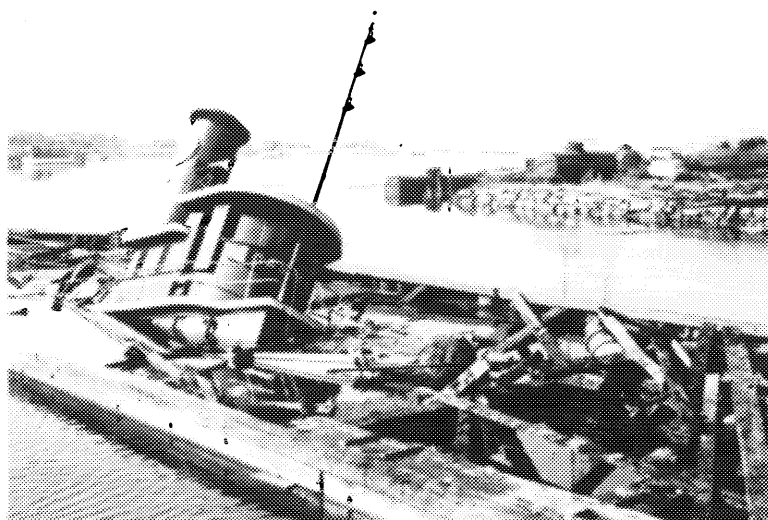
WEST PALMOUTH, MASS.
Highway bridge damage.



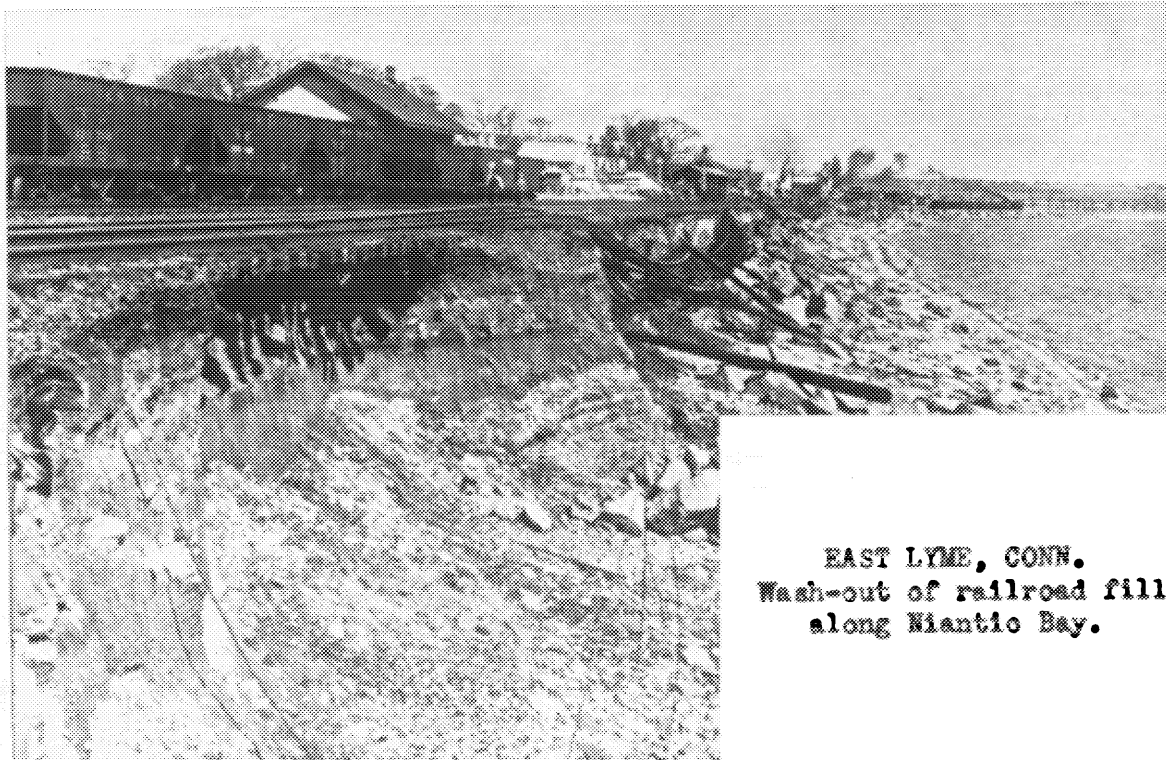
WOODS HOLE, MASS.
Damage to abutment
of bridge at
entrance to
Eel Pond.



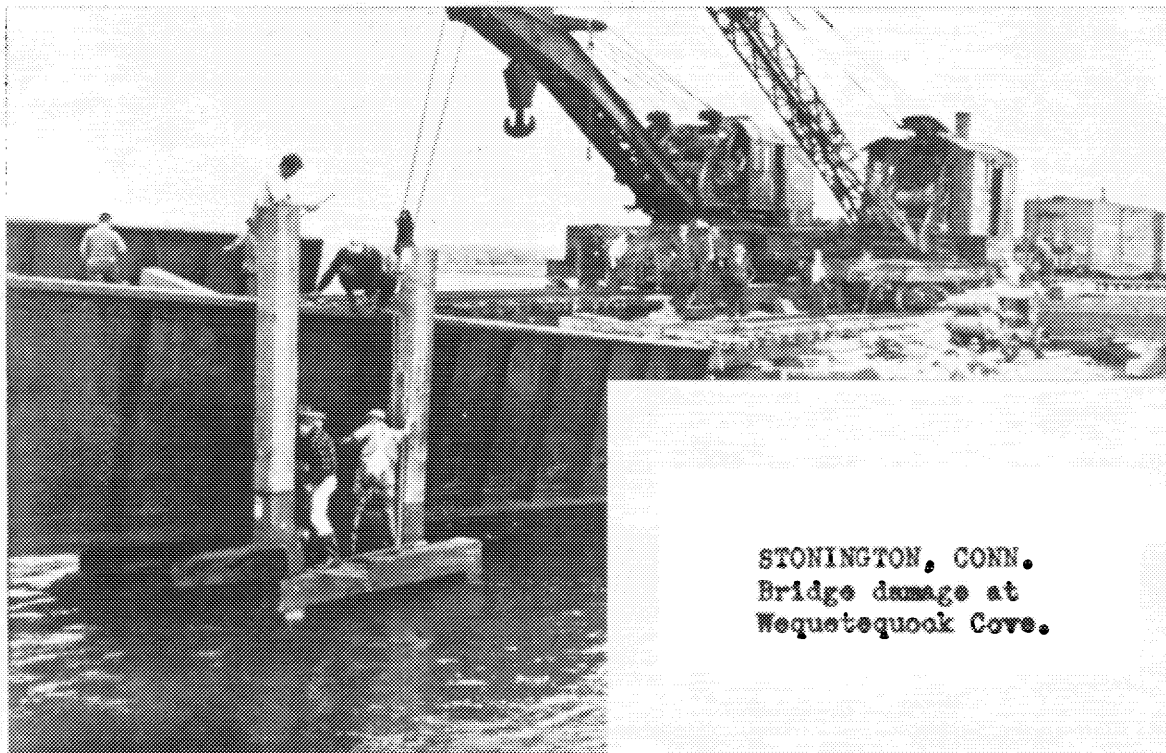
PROVIDENCE, R. I.
Flooded freight yard and sheds.



PROVIDENCE, R. I.
Tug GASPEE sunk in fender prevented bridge
opening. Tank cars floated away.



EAST LYME, CONN.
Wash-out of railroad fill
along Niantic Bay.



STONINGTON, CONN.
Bridge damage at
Wequetequock Cove.

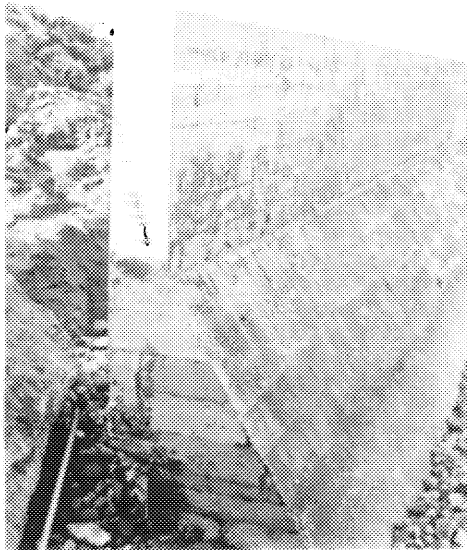
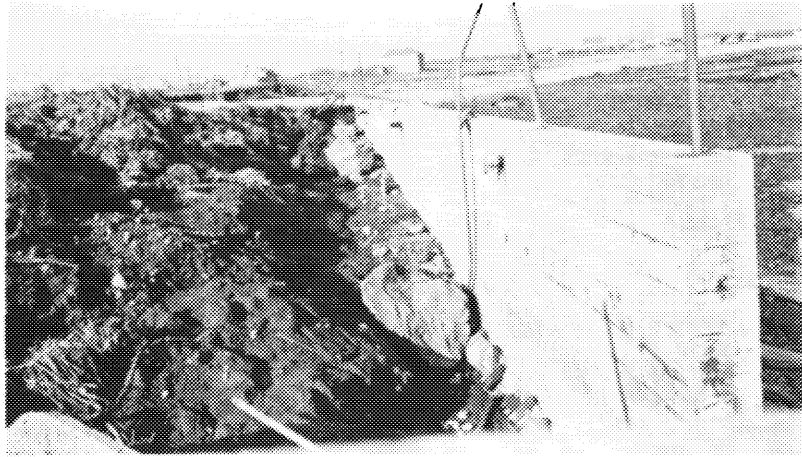


Broken seawall

SAKONNET POINT, R. I. Headland erosion and seawall destruction.



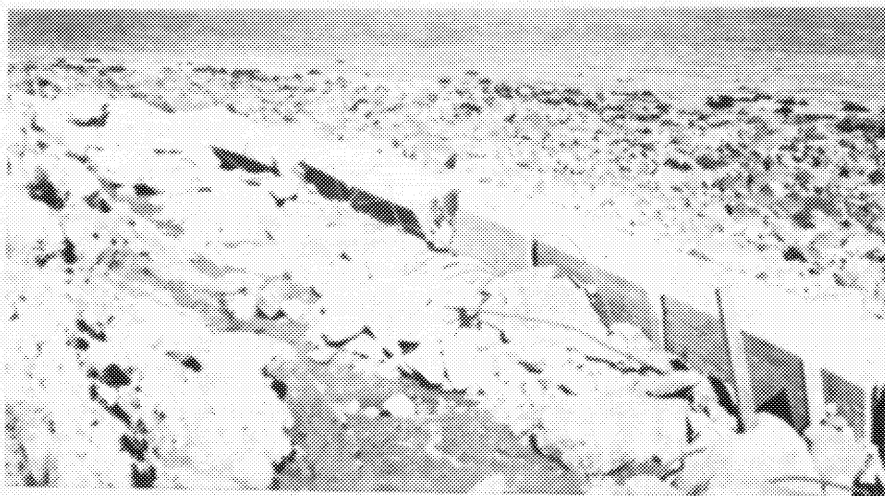
NEWPORT BEACH, R. I.
Headland erosion and
seawall destruction.



NARRAGANSETT, R. I.
 North of Point Judith
 Upper: Erosion behind
 seawall.
 Lower: Section of un-
 damaged seawall.



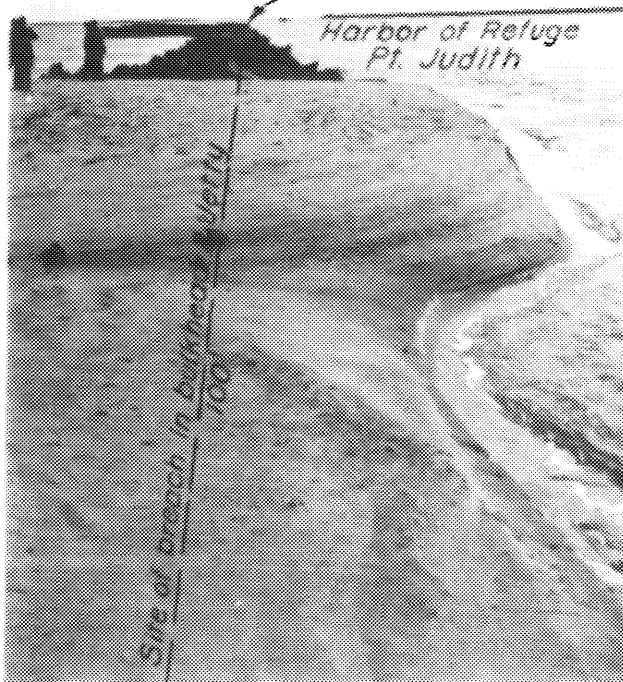
NARRAGANSETT PIER, R. I.
Headland erosion; seawall and highway destruction.



POINT JUDITH, R. I.
Headland erosion and overturned seawall.



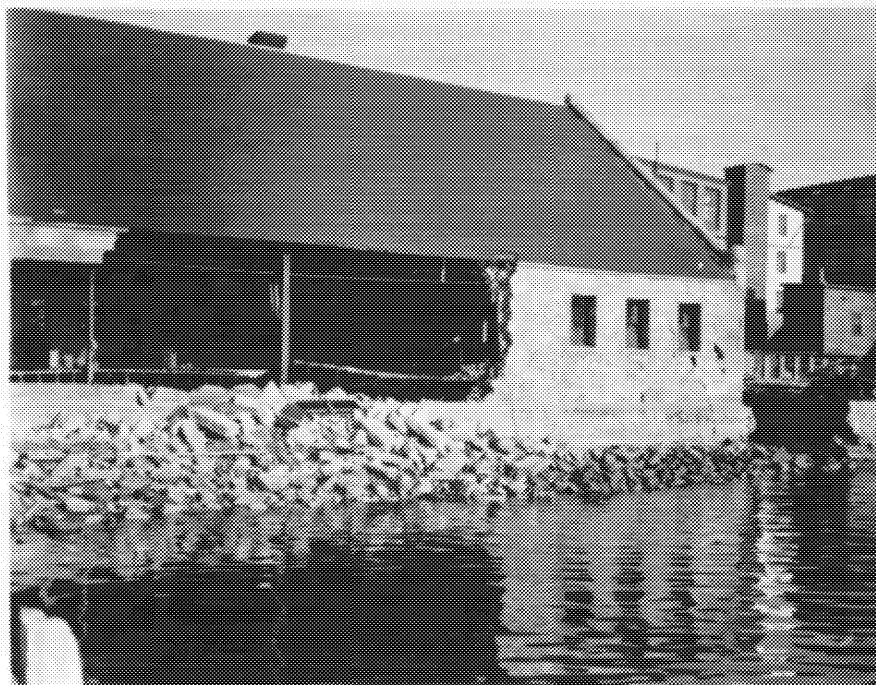
State Jetty



GALILEE, NARRAGANSETT, R. I.
Entrance to Point Judith Pond.

Upper: Sept. 23, 1938. Breach
in bulkhead and jetty.

Lower: Oct. 10, 1938. Breach
filled by natural sand
movement.



BRISTOL, R. I.
Substantial stone wall of Armory torn away
by wave and floating debris.



NEWPORT, R. I.
Substantial pier wrecked
by hurricane wave.



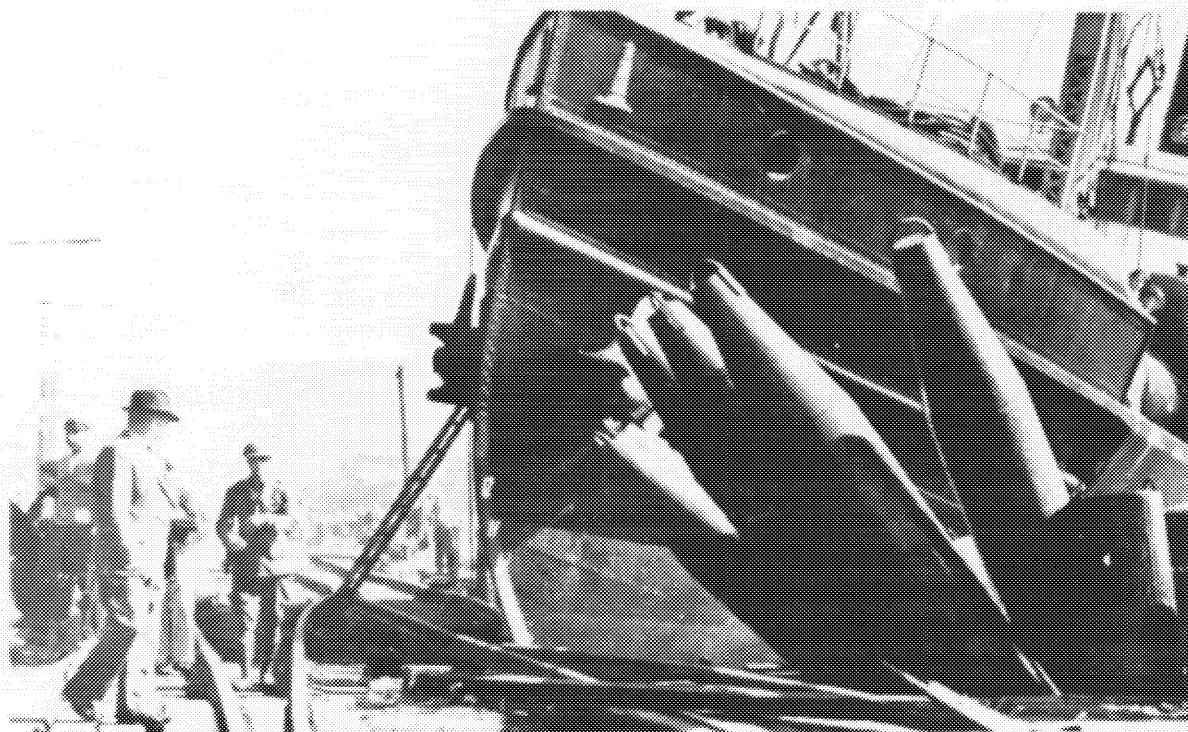
NEWPORT, R. I.
Damage to Brenton Point Coast Guard building
on Price Neck.



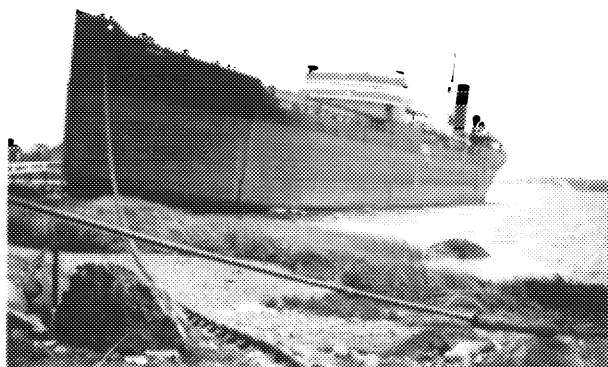
PROVIDENCE RIVER, R. I.
Bullock Point Light.
Wall of building torn
away by seas.



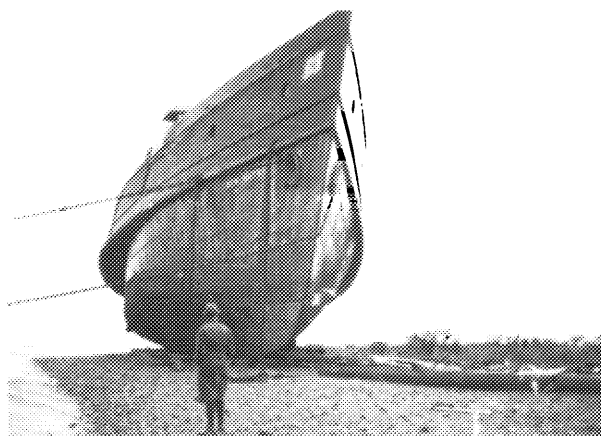
PROVIDENCE, R. I. Coal barges landed in South Water Street near Point Street Bridge. Lumber floated away from yards.



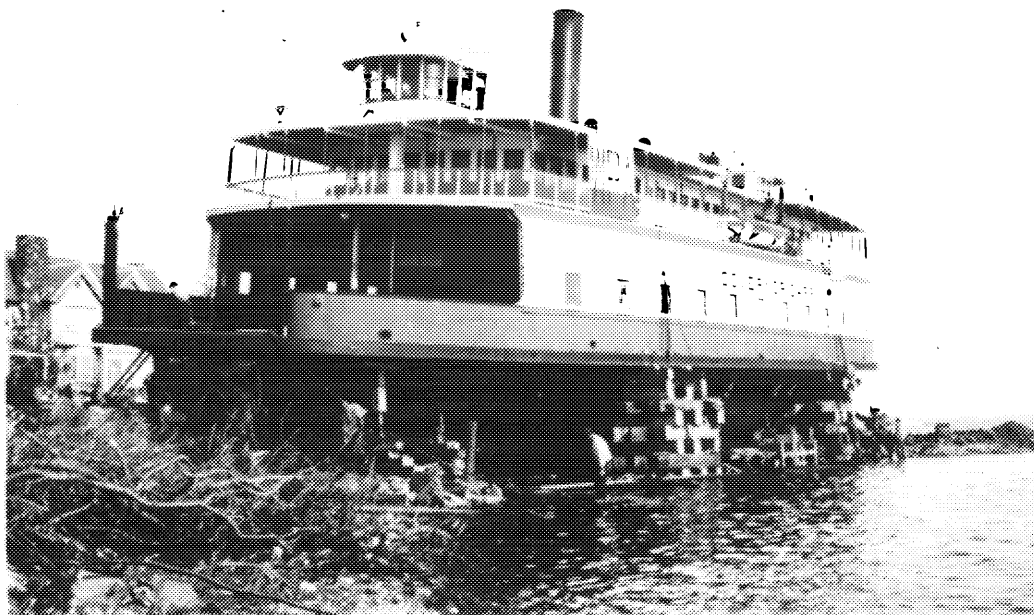
NEW LONDON, CONN.
Lighthouse tender TULIP out into railroad tracks.



SOMERSET, MASS.
Oil tanker PHOENIX
aground.



SOMERSET, MASS.
Freighter NEW HAVEN
aground.



JAMESTOWN, R. I. Ferry GOVERNOR CARL carrying car.



BARRINGTON, R. I. Pleasure craft piled up at
bridge over Barrington River.



WAKEFIELD, R. I. Yachts cast ashore and piled
behind building.



PROVIDENCE, R. I. Bus, trucks and buildings flooded on Fountain Street. Railroad station in background on left.



PROVIDENCE, R. I. Easterly approach to Point Street bridge flooded.

WESTERLY, R. I.
Ruins of Weekapaug
Inn and seawall



NARRAGANSETT PIER, R. I.
Ruins of Dunes Club.



BEFORE HURRICANE



AFTER HURRICANE

WATCH HILL, WESTERLY, R. I.
Looking westward along Napatree Beach. Note wooden groins which survived.



CONIMICUT POINT, WARWICK, R. I.

Many dwellings were swept off this foreland; foundations only remain.